Lake Chad Regional Economic Memorandum

Development for Peace

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Attribution—Please cite the work as follows: Rogelio Granguillhome, Marco Hernandez, Samantha Lach, Takaaki Masaki, and Carlos Rodríguez-Castelán (2021). *Lake Chad Regional Economic Memorandum: Development for Peace*. Washington, D.C.: The World Bank.

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Acknowledgments

This report was prepared by a joint Macroeconomics, Trade, and Investment Global Practice and Poverty and Equity Global Practice team led by Marco Hernandez, Takaaki Masaki, and Carlos Rodríguez-Castelán. The authors of this report are Rogelio Granguillhome, Marco Hernandez, Samantha Lach, Takaaki Masaki, and Carlos Rodríguez-Castelán.

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The report benefited from inputs and comments from Hiromi Akiyama, Luis Alberto Andres, Federico Antoniazzi, Abul Azad, Oliver Balch, Armel Castets, Olivia D'Aoust, Catherine Marie Rose Defontaine, Johanna Damboeck, Luc Gendre, Elaine Chee En Hui, Guillaume Laurent Marie Jeanrot, John Keyser, Aditya Khaparde, Jonathan William Lain, Jean Christophe Maur, Aimee Marie Ange Mpambara, Adrian Morel, Antonio Nucifora, Aissatou Ouedraogo, Vijay Pillai, Edward Rackley, Andrew Roberts, Aly Sanoh, Aboudrahyme Savadogo, Franck Taillandier, Issa Bitang A. Tiati, Emilija Timmis, Tara Vishwanath, and Albert Zeufack.

The team is grateful to the peer reviewers for their excellent comments and suggestions: Nancy Lozano, Nicolas Perrin, and Siddharth Sharma. The team is also grateful to discussants of the technical papers during an author's workshop: Erhan Artuc, Paul Brenton, Joanne Gaskell, Aparajita Goyal, Bob Rijkers, Emmanuel Skoufias, Hernan Winkler, and Roman Zarate.

This project was conducted under the overall guidance of Deborah L. Wetzel (Director of Regional Integration for Africa), Abebe Adugna (Regional Director for Equitable Growth, Finance, and Institutions), Francisco Carneiro (Practice Manager for Macroeconomics, Trade, and Investment), Andrew Dabalen (Practice Manager for Poverty and Equity), Johan A. Mistiaen (Practice Manager for Poverty and Equity), and Pierella Paci (Practice Manager for Poverty and Equity).

Rocio Manrique and Santosh Kumar Sahoo assisted the team, and the report benefited from editing by Robert Zimmermann.

Executive Summary

The context of the Lake Chad Regional Economic Memorandum: Understanding underdevelopment. The Lake Chad region is an economically and socially integrated area located in west-central Africa. Spanning Cameroon, Chad, Niger, and Nigeria, this semiarid region faces a combination of long-term, structural barriers to development, layered on top of which are a complex set of exacerbating, near-term problems. The result is a situation of acute fragility that is trapping the region's 30 million inhabitants in a vicious cycle of low growth and endemic poverty. In turn, these conditions are fueling violence, conflict, emigration and displacement, land degradation, youth alienation, and a general sense of dissatisfaction with government institutions. In a region with limited traditional data, this memorandum presents new quantitative and qualitative evidence by integrating and leveraging existing population censuses, household surveys, administrative data, and information derived through the application of big data techniques to previously untapped datasets, such as nighttime light intensity, remote sensing data, and other geolocated data. This research offers valuable new insights on the nexus between suboptimal territorial development, on one hand, and climate change and conflict, on the other.

Development in the Lake Chad region is not only limited, but has shown few signs of historical improvement. The metrics of the socioeconomic development of the region paint a challenging picture. The region is characterized by high rates of poverty, low human capital, and poor access to key services. In the last three decades, economic activity and household incomes have been decreasing. The region has one of the highest population growth rates in the world, and fertility rates average around 5 children per woman. Communities in the vicinity of the lake are lagging compared with the socioeconomic standards in other parts of Cameroon, Chad, Niger, and Nigeria, which are already underperforming compared with other developing economies worldwide. For instance, in Nigeria's North East, which flanks the lake to the southwest, poverty rates are estimated at over 70 percent, almost double the rate in the rest of the country.

The underdevelopment or lagardness of the Lake Chad region is best understood as an agglomeration of interconnected factors. This memorandum identifies and examines the interplay within and among long-standing structural factors (such as weak governance, lack of access to basic services, limited market accessibility, limited connective infrastructure, and socioeconomic exclusion), as well as with two exacerbating factors that have become more prominent in recent decades: violent conflict and climate change. The report then seeks to show the interconnections between these two distinct sets of challenges, namely, the long-term and structural challenges on the one hand and the more recent exacerbating factors on the other. The use of a spatial lens reveals a more granular and nuanced picture of the poverty trap in which the Lake Chad region has been caught. This opens the door to holistic policy recommendations, holding out the hope that the vicious cycle of suboptimal development and fragility in which the region is currently caught can be broken and replaced with a virtuous circle of economic growth, job creation, and poverty reduction.

Three Ds help explain territorial development: distance, density, and division. In line with the interrelational nature of the Lake Chad region's underdevelopment, this memorandum adopts a cross-cutting approach to the analysis of the territorial hurdles faced by businesses and individual economic agents in the region. The first of the three spatial lenses the report adopts is *density*, which, as applied here, is defined as the economic mass or output per unit of land area (often measured as gross domestic product [GDP] per square kilometer). Economically active urban settlements are generally taken as a strong indicator of density (and growth potential). However, the Lake Chad region is lacking in this element. Except for the cities of N'Djamena in Chad and Maiduguri in Nigeria, which, together, account for around two million inhabitants, the vast majority of urban settlements in the region have fewer than 20,000 people. Rural migration is an ongoing trend in the region, and, because people are being displaced by conflict, the region has witnessed refugee urbanization rather than urban dynamism. The second lens is *distance*, which is the ease or difficulty of transporting goods, services, labor, capital, information,

and ideas between two locations. The Lake Chad region's record is weak on this measure. For instance, nearly two-thirds of the region's rural population live more than two kilometers from an all-season road. Couple this with low phone and internet connectivity, plus limited access to electricity and other basic services, and the effect on development is highly prejudicial. Completing the 3Ds is the concept of division, which is defined in both physical and social terms. *Division* captures tangible barriers to growth, such as crossborder trade restrictions, and differences in access to services and economic opportunities across population groups such as based on sex, age, economic activity (for example, between pastoralists and farmers), as well as displaced individuals and other vulnerable groups. The effect of each of the 3Ds alone is a serious impediment to growth, but, together, they make up a major derailment along the track to the inclusive growth of the Lake Chad region. Thus, this memorandum not only analyzes these three factors on their own, but also the interplay among them.

Two Cs—climate change and conflict—are exacerbating the region's fragility. The memorandum also focuses on two interrelated factors that are deepening underdevelopment in the Lake Chad region. The first is *climate change*, a worldwide phenomenon that presents significant, immediate, and unique challenges among people living in the vicinity of Lake Chad, at the center of the Sahel. Across the Sahel, temperatures are rising 1.5 times more quickly than the global average, leading to hotter general conditions and more erratic weather patterns. Droughts have become more severe and more recurrent in recent decades. The variability in the size of the lake—which shrank between the 1960s and the mid-1990s, but has been recovering since then—has affected livelihoods. Given that the region's agriculture is almost exclusively rainfed, the rise in temperatures is associated with major issues in food security and the incomes of farmers and herders. A second factor that is intensifying fragility is represented by *violence and conflict*, notably, the destabilizing activities of Boko Haram, a militant insurgency group that emerged in Nigeria in 2009 and then spread to the other three countries in the Lake Chad region. Between 2009 and 2019, conflict in the region led to the displacement of an estimated 2.7 million people. In total, about 12.8 million people need humanitarian assistance. Nigeria's North East has been particularly badly affected. As with the 3Ds, the 2Cs feed into each other. The reduction in yields and farmer incomes caused by deteriorating climate conditions is lowering the opportunity costs of participating in violence. Likewise, the rising levels of violence are impinging on the capacity of governments to undertake climate mitigation and adaptation measures. A positive temperature anomaly of one standard deviation increases annual conflict events in the region by 17.6 percentage points. Similarly, conflict events in the Lake Chad region rose by an average of 8.9 percentage points in response to a negative anomaly of one standard deviation in a district's degree of greenness. Moreover, the impact of climate on conflict is strongest in areas that are largely agrarian and more densely populated.

The policy response needs to reflect the recognition that the development challenges in the Lake Chad region are interconnected. Given the extent of the region's socioeconomic challenges, a big push is required in policies and programs that can effectively promote territorial development, while addressing the drivers of fragility. This will require a strong consensus and prioritization of measures at the community, local, state, national, and regional levels. Measures aimed at tackling the region's challenges in isolation are not likely to result in sustained progress. An implication of the analysis in this memorandum is that an approach focusing on holistic policy levers represents the best chance of breaking the region's vicious cycle of suboptimal development and fragility. As exemplified by the analysis of the 3Ds and 2Cs, the factors behind Lake Chad's stubbornly high poverty rates are intimately interlinked and profoundly self-perpetuating. For instance, weak connective infrastructure (large distance) is shown to link to smaller economic agglomerations (low density), which reduces opportunities for trade and social dialogue and inclusion (high division). As all of this plays out against the backdrop of climate shocks and violent conflict, the vicious cycle is reinforced dangerously.

This memorandum concludes with policy options in four cross-cutting areas: infrastructure, trade, governance, and natural resource management. First, investing in infrastructure would help close connectivity gaps in the Lake Chad region, leading to higher productivity and better-quality jobs, particularly in rural areas. Important steps include improving road connectivity between cities and rural areas, expanding the delivery of basic services, and promoting digital infrastructure. Second, enhancing trade and regional integration would serve to reduce distance and division, leading to stronger agricultural value chains, higher incomes, improved food security, and greater stability. Promoting fishing and fish trading would be a timely step, as would be the gradual facilitation of crossborder trade, including through tariff harmonization (by taking advantage of the opportunities inherent in the Africa Continental Free Trade Area) as well as the visa-free movement of people. Third, strengthening the rule of law and the functioning of institutions through enhanced governance at the community, local, national, and regional levels are crucial for promoting the better delivery of basic services, which in turn are pivotal to address persistent gaps in human capital outcomes, to mitigate the devastating effects of violence conflict on lives and livelihoods, and to promote social inclusion. Improving coordination between federal and subnational governments, mobilizing domestic revenues more effectively, improving data for evidence-based policy making, and investing in local government capacity is vital to restoring a positive government presence in the Lake Chad region, as are measures to restore social cohesion and trust between citizens and the state. Fourth, the report recommends a renewed focus on natural resource management, including efforts to strengthen the sustainability of food systems and more effective land and water management practices suited to local agroecological conditions. This would require a solid regulatory environment and targeted support for producers, such as through the provision of credit, inputs, and extension services, as well as investments in technological innovation and knowledge transfers. Given the key coordinating role of the Lake Chad Basin Commission (LCBC), improvements to the organization's operating capacity are also a priority.

Pathways to development and peace. The policy levers highlighted in this memorandum are associated with elements of the 3Ds and 2Cs and have the potential to halt and reverse the self-reinforcing negative feedback loops of the vicious cycle. The goal is to inform the policy debate and build a consensus for integrative measures that will enable greater local density in economic production (by agglomerating labor and capital), reduce the distance to leading areas (increasing the flow of capital, labor, goods, and services), and lower divisions (causing living standards to converge), while addressing the conflict head-on (consequently increasing economic integration) and mitigating climate change (making income-generating activities more productive and resilient). A holistic agenda of this nature presents an immediate and realistic opportunity to break the Lake Chad region's cycle of underdevelopment and fragility and kickstart a positive cycle of more inclusive and resilient economic growth that is supported by broad societal consensus, high-level political commitment, and strategic and sustained policy implementation.

Part I: Overview of the Lake Chad Regional Economic Memorandum

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1.1 Introduction

1.1.1 Rationale

> *The region is noteworthy for important archaeological discoveries, its role in trans-Saharan trade, and its association with historic African kingdoms...*
>
> *The Chad basin contains the earliest evidence of hominin occupation yet found in western Africa.*
>
> *Gritzner (2021)*

The Lake Chad region is an economically and socially integrated area straddling four countries in West and Central Africa, namely, Cameroon, Chad, Niger, and Nigeria. The lake is situated in an interior basin, which was formerly occupied by a much larger ancient sea, sometimes referred to as Mega-Chad.[1] The region appears to have been continuously settled since 500 BCE.[2] Today, many social and economic indicators confirm that the area is a lagging region, though its rich natural resources and young population point to untapped economic potential. The Lake Chad region is a geographical crossroad and an epicenter in terms of the cultural, historical, and sociological characteristics of the local communities in the area. The historical economy of traditional livelihoods and trade around the lake has traditionally been mobile and crossborder. Despite the heterogeneity of structural factors in the basin countries, the crossborder movement and trade across the basin and the cultural ties and common identity in the area translate it into a distinct region. This region is currently facing shared security, economic, and climatic troubles.

An estimated 30 million people live in the Lake Chad region.[3] The area consists of 10 national regions: the Far North Region in Cameroon; the Chari-Baguirmi, Hadjer-Lamis, Kanem, and Lac regions in Chad; the Diffa and Zinder regions in Niger; and Adamawa, Borno, and Yobe states in Nigeria (see Map 1.1 and Map 1.2). The majority of the labor force is occupied in primary sector activities—mostly agriculture, cattle herding and fishing—and indirect employment in related activities, such as trade, transport, and manufacturing. These economic activities contribute to jobs and food security among residents in the lake's hinterlands and linked to the two regional metropolises with seven-digit populations: N'Djamena, the Chadian capital, and Maiduguri, the capital of Borno State in Nigeria.

The population in the Lake Chad region is growing at a rapid pace, putting additional pressure on the limited resources and basic services. Fertility rates are high, and the total population in the Lake Chad Basin countries is projected to double over the next 25 years.[4] High population growth poses challenges in access to basic services, such as electricity and piped water; where access rates are already among the lowest in the region, with implications for human capital. Literacy and completion rates in primary education in the areas around the lake are significantly lower than in the rest of the respective countries. Furthermore, rather than converging, the gap in access to core services has been widening between the Lake Chad region and other parts of the countries.

Lagging in social and economic indicators, the Lake Chad region is characterized by weak territorial development. Compared with other parts of the basin

1 Gritzner (2021).

2 Ibid.

3 World Bank calculations based on the proposed administrative definition of the Lake Chad region, Linard et al. (2012), and remote-sensing data of Population Counts (dashboard), WorldPop, University of Southampton, Southampton, UK, https://www.worldpop.org/project/categories?id=3.

4 UNFPA (2017). The term Lake Chad Basin countries is used indistinguishably with Lake Chad region countries throughout the report to denote the four countries of the study: Cameroon, Chad, Niger and Nigeria.

countries, the Lake Chad region exhibits significantly higher poverty rates, chronic human capital deficits, and a historical lack of access to basic services and infrastructure. It has experienced little economic progress over the past three decades. The declining water level of the lake until the mid-1990s pushed people to migrate from rural to urban areas (although, since then, the water level has been recovering). Currently, the region is characterized by widening spatial gaps because urban agglomerations in the region are growing more quickly than rural areas. Rural areas have limited access to connective infrastructure; people are twice as likely to be disconnected from main roads and thus from access to markets and economic opportunities. In both urban and rural settings, women, youth, displaced persons, and other vulnerable groups face unequal access to services and to income-generating activities.

The long-term suboptimal territorial development challenges are exacerbated by the interplay of conflict and climate change. Ten years of conflict, driven by the Boko Haram insurgency, have left an estimated 12.8 million people in need of humanitarian assistance in the Lake Chad region, 2.7 million of whom are people displaced by the conflict.[5] Human displacement and the disruption of markets and value chains because of the physical destruction of facilities and direct threats against traders have resulted in loss of productive assets and inputs. While the region has traditionally been a commerce hub connecting the four basin countries and providing ties with North Africa, crossborder trade and economic activities around Lake Chad have also been disrupted by the Boko Haram conflict. Counterinsurgency measures, such as border and road closures, restrictions on farming and fishing, and the movement of goods and people, have also put a damper on economic activity.[6] The intensity of fighting has tapered off in recent years, but the conflict has spread from its original location in Nigeria's North

Map 1.1: Lake Chad area

Source: Magrin, Lemoalle, Pourtier, 2015. *Atlas du lac Tchad.*

Source: Magrin et al. 2015.

Map 1.2: Administrative definition of the Lake Chad region

Sources: Masaki and Rodríguez-Castelán 2021; data of GADM Database of Global Administrative Areas, Environmental Science and Policy, University of California, Davis, CA, https://gadm.org/.

5 Of the 12.8 million people in need of humanitarian assistance, 10.6 million are in the three most highly affected states, Adamawa, Borno, and Yobe, in Nigeria's North East (USAID 2020).

6 UNDP and OCHA (2018).

East and currently affects all four countries surrounding Lake Chad.[7]

In addition, climate change is increasingly becoming a significant risk to livelihoods and food security across the region. Rising temperatures and increasingly erratic rainfall patterns have rendered precarious the livelihoods of farmers and fishers who rely critically on uncertain water resources. Moreover, the greater frequency of climate anomalies (e.g., rainfall shortages, rising temperatures, and aridification) has been associated with a rise in conflict activities in the region.

The effects of conflict and climate change are painfully visible through remote-sensing technology. The economic effects of conflict can be seen from outer space. Areas directly or indirectly affected by Boko Haram are experiencing slower rates of growth (measured by nighttime lights). There is evidence of spillover effects. Thus, even at a time when Boko Haram activity was only occurring in Nigerian territory, it was possible to observe the negative effects on the neighboring countries of Cameroon, Chad, and Niger. There is also evidence of the long-term negative effects of climatic factors on population growth and economic agglomeration. As a result of the shrinkage of Lake Chad between the 1960s and the 1990s, areas near the lake experienced substantially slower population growth, particularly in Cameroon and Niger. This is likely explained by the loss of economic opportunities, including because the receding lake offered less irrigation for agriculture and cattle herding and lower incomes from fishing. Since the late 1990s, the level of the lake has been recovering.

This project helps close a critical knowledge gap by identifying opportunities to promote sustainable and inclusive economic growth in the Lake Chad region. Existing policy research is extremely thin. The report draws insights from seven original technical papers that speak to different facets of the interlinked developmental challenges in the region.[8] Given the limited availability of rigorous economic studies in the area, this research helps bridge an important knowledge gap. A better understanding of the interlocked challenges and mechanisms that have trapped the region in a low-growth, high-poverty equilibrium is essential to identifying policy instruments to improve service delivery, provide stability, and strengthen economic opportunities.

One of the main contributions of this Lake Chad Regional Economic Memorandum (LCREM) is the definition of a novel analytical framework to elaborate a comprehensive diagnostic of territorial development challenges in the presence of conflict and climate change. The proposed analytical framework captures the vicious cycle between suboptimal territorial development in the region and the systemic risks associated with the violent conflict and climatic shocks that the region faces and that negatively affect development outcomes. The framework helps identify policies with the potential to improve territorial development and reduce violent conflict and fragility, thereby allowing developing regions to escape the self-perpetuating vicious loop that makes them diverge from their long-term potential.

Another key contribution of this LCREM is the production of an innovative data-driven diagnostic on inclusive growth across the region in a context of limited data availability. The LCREM integrates both traditional and innovative sources of data to provide a rigorous economic analysis of the Lake Chad region. The ability to provide data-driven analysis is a particularly important feat, given that the data environment in the region is extremely poor. Primary data collection in the area is difficult because of tenuous security, access constraints, and—more recently—the COVID-19 pandemic,

7 The nature and frequency of violent events in Lake Chad Basin countries can be tracked through ACLED (Armed Conflict Location and Event Data Project) (dashboard), Robert S. Strauss Center for International Security and Law, Austin, TX, http://www.acleddata.com/; GTD (Global Terrorism Database), National Consortium for the Study of Terrorism and Responses to Terrorism (START), University of Maryland, College Park, MD, https://www.start.umd.edu/gtd/; UCDP (Uppsala Conflict Data Program) (database), Department of Peace and Conflict Research, Uppsala University, Uppsala, Sweden, http://ucdp.uu.se/?id=1.

8 See Appendix 1.C for a list of the technical papers prepared for this report.

which make in-person data collection unfeasible. In this particularly difficult data environment, the LCREM has performed extensive stocktaking and data-generation based on traditional sources of data, including household surveys, censuses, and administrative data, and new sources of data from satellite imagery and remote-sensing technology. This data collection and generation process has involved digitizing historical census population data dating back to the 1950s and standardizing and integrating existing micro-level household surveys available for the Lake Chad Basin countries. The new sources of data—remote-sensing and satellite data—leverage spatially and temporarily granular data on various development outcomes, including local economic activities (for example, nighttime lights), agricultural productivity, conflict, climate (rainfall, temperature), and infrastructure (roads, electricity, digital infrastructure).

The value of this LCREM also resides in its integral diagnostic of regional development challenges, focusing on a particular territory nested within several countries. Unlike a traditional Country Economic Memorandum (CEM) produced by the World Bank, which offers a country-level diagnostic of key development challenges and a policy agenda in a *single* country, this LCREM presents a comprehensive analysis of development challenges that are specific to the Lake Chad region. And it identifies policy directions that the Lake Chad Basin countries may pursue to facilitate their growth. This regional or territorial focus is unique and particularly important in framing current policy debates around inclusive growth because, around the world, poverty has become spatially concentrated and economic progress highly uneven across space.[9] Unlocking economic opportunities for lagging regions thus entails regional interventions and coordination across different countries.

Given its novel framework and analytical approach in a context of limited data availability and its focus on a set of subregions across countries, this report represents a model for other, similar settings. Regions around the world face a combination of territorial development challenges and a substantial risk of systemic shocks and are often caught in suboptimal equilibriums. The analytical framework and approach depicted in this LCREM, which explicitly address the feedback mechanisms among the challenges in a solution-oriented manner, can be useful beyond Lake Chad. It can help inform policy interventions in settings experiencing a similarly vicious cycle to identify challenges and opportunities for inclusive growth. In addition, because the characteristically limited data on the Lake Chad basin is also the typical setting of many lagging regions, the methods for data integration and analysis used in this report could also help inform evidence-based policy making in numerous data-poor areas.

1.1.2 Road Map of the Report

This report sheds light on the interlocked long-term territorial development challenges and the recently realized systemic risks affecting the Lake Chad region. It summarizes the findings of seven technical papers, each investigating different aspects of the interlinked challenges faced by the region. These studies are accompanied by complementary research on labor market and geospatial socioeconomic trends, as well as by a review of the thin literature on economic development across the region. In addition to presenting the main results of the technical papers, the report positions the findings in the broader context of an analytical framework depicting the feedback mechanisms between the region's territorial development gaps and the self-reinforcing link to shocks, namely, violent conflict and climate change. **This analytical framework is presented in Section 1.2**. The rest of the report is structured as follows.

Section 1.3 describes the main social and economic trajectories in the region. It reviews long-term demographic trends—suggesting that population growth in the region is among the highest worldwide—and finds

9 See *World Development Report 2009* (World Bank 2009).

limited access to basic services in the areas surrounding the lake. Poverty and socioeconomic trends show that the region is lagging relative to other parts of the basin countries, and local economic dynamics indicate that the region has experienced little economic progress over the past decades. Agriculture is the main sector of economic activity in the Lake Chad region, accounting for the labor of a large share of young workers, as shown by the analysis of labor market data. Wage employment is limited, and the gap in the quality of jobs in the region extends into gaps by sex.

Section 1.4 argues that the low-growth, high-poverty equilibrium observed in the region is closely linked to the region's economic geography. A low degree of economic *density* (concentration of economic activity), in combination with great *distance* and wide *divisions* that limit the ease of movement of people, goods, capital, and ideas, appears to be derailing the region from a sustainable track of growth. The region shows low levels of density and urbanization, whereby urban agglomerations tend to grow more quickly than rural areas, with widening spatial gaps and a lack of regional convergence. Connectivity gaps limit access to markets and economic opportunities among people, particularly in rural areas, with implications for local economic development. Over the past 10 years, border closures in response to the Boko Haram conflict have limited mobility and the historically strong crossborder trade in the Lake Chad Basin. In addition to hampering trade, violent conflict has aggravated social exclusion in the region, curtailing access to services and income-generating opportunities, particularly among vulnerable groups. Violent conflict has driven the forced displacement of people in the region, resulting in one of the worst humanitarian crises in 2019.[10]

Section 1.5 discusses how the impact of climatic variation and violent conflict experienced in the region interlink with and exacerbate the territorial development challenges. Highly dependent on agriculture, the Lake Chad region is at particular risk from harsh environmental conditions. The region has experienced a higher share of droughts compared with other areas in the basin countries, with implications for livelihoods and food security. More regular rainfall is associated with positive effects on local economic growth. The section also shows that climate anomalies, such as deteriorating vegetation, rising temperature, and erratic rainfall are closely linked with conflict events in the Lake Chad region, suggesting that there is a climate-conflict trap. Violent conflict has had significant negative economic effects in the region by disrupting trade and shattering agricultural production. The downturn in local economies is not only visible in the directly attacked areas, but has also spilled over to neighboring regions. The slump in economic activity is particularly harsh on less well developed and less well connected urban areas, highlighting the link among gaps in territorial development, conflict, and suboptimal development outcomes.

Section 1.6 presents policy directions structured around four crosscutting themes: infrastructure, trade, governance, and natural resource management. The crosscutting nature of these themes encourages the exploration of potential synergies across challenge areas. The discussion in the section aims to inform policy-making efforts to strengthen territorial development and mitigate the impacts of conflict and climate change. Such endeavors can increase the likelihood of breaking free from the self-reinforcing negative mechanisms and boost the potential return of the region to a path of stability and inclusive economic development.

10 OCHA (2019).

1.2 Analytical Framework

Socioeconomic and governance challenges across the region are interlocked with issues of fragility, conflict, and harsh environmental conditions, which have trapped the region in a low-growth, high-poverty cycle. The region faces multidimensional challenges related to weak governance, low human capital, limited market accessibility and economic opportunities, poor citizen security, regional instability, limited connective infrastructure, and engrained social exclusion.[11] The poor quality of services in the region has been exacerbated by the destruction of public and private infrastructure.[12] These mutually reinforcing challenges have resulted in a fragile region characterized by conflict and violence, endemic poverty, limited economic opportunities, especially among youth, land degradation, insecurity, and general dissatisfaction with public institutions. Climate change and demographic trends—the rapid growth and young age-structure of the population—amplify and exacerbate these threats. A lack of central government presence that predates the ongoing crisis, particularly in rural areas, has left a governance void in the region.[13] Already weak, the social contract between citizens and the state has eroded in recent years, as governments are increasingly less able to provide basic public services in the region as a result of the widespread insecurity. This has reduced the trust of citizens in government, which also fuels the conflict, especially where a sense of exclusion exists.[14] Armed rebel groups have taken advantage of this gap in governance, particularly in public service delivery, to provide valued access to health care, food, religious education, and funding that is aimed at strengthening their position.[15]

This report proposes an analytical framework based on two main components: (a) a self-reinforcing link between suboptimal territorial development and fragility, conflict, and violence (FCV) and challenges relating to climate change and (b) policy instruments aiming at strengthening territorial development and mitigating risks. The report is guided by the analytical framework illustrated in Figure 1.1 that draws analytic elements from *World Development Report 2009: Reshaping Economic Geography* (World Bank 2009), *World Development Report 2010: Development and Climate Change* (World Bank 2010), and *World Development Report 2011: Conflict, Security, and Development* (World Bank 2011).[16] Furthermore, this LCREM is aligned with the World Bank FCV strategy's two pillars of engagement: (a) preventing violent conflict and interpersonal violence and (b) mitigating the spillovers of FCV.[17] The center of the illustration in Figure 1.1 helps explain the outcomes observed in the region, including low growth, high poverty rates, and a low human capital index. The framework depicts the feedback between suboptimal territorial development and systemic risks prevalent across the region, such as violent conflict, weather shocks, and resource scarcity. All these risks negatively affect development outcomes, which results in a vicious cycle. This negative feedback loop deviates lagging regions from their long-term economic potential, leading to lower

11 Such as exclusion from local decision-making processes and capture (of policies, services) by elites (World Bank 2018).

12 Al Jazeera (2017); Obi and Eboreime (2017). Further details available under the '3.4 Human capital outcomes and access to basic services' section, below.

13 Magrin and Perouse de Montclos (2018).

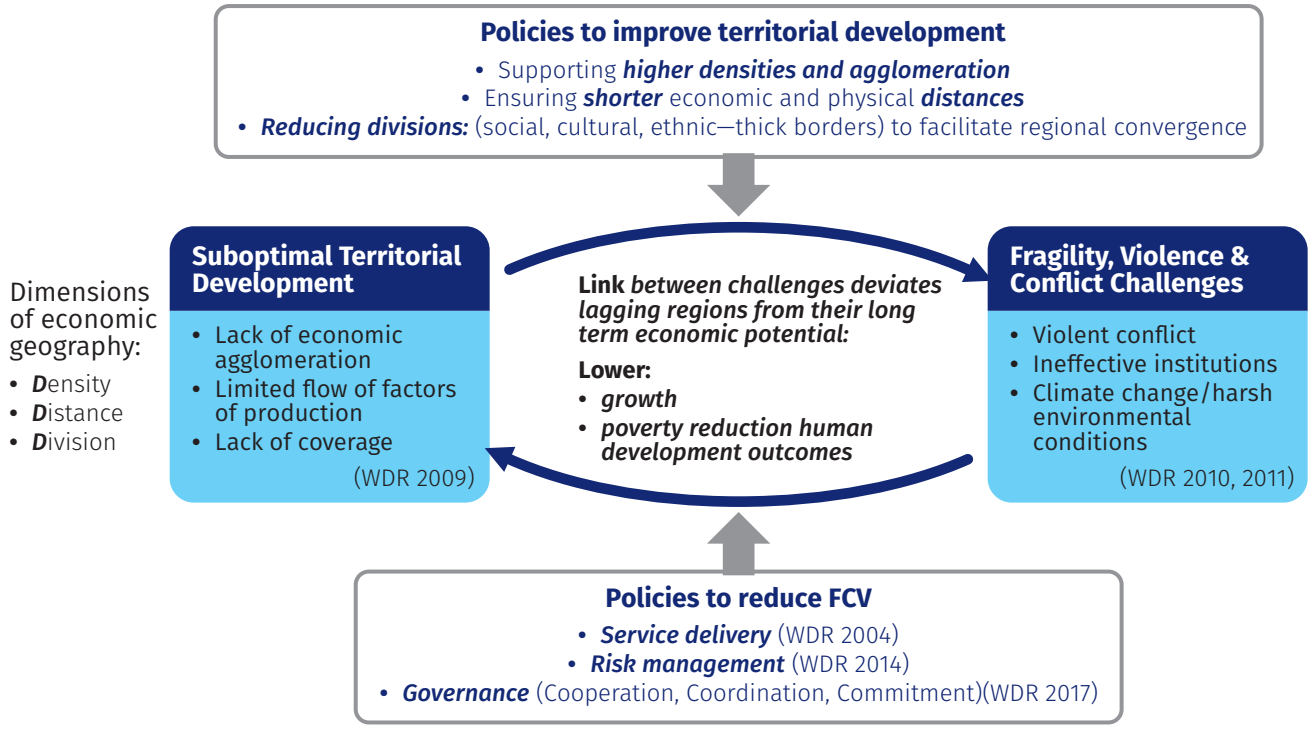
14 Magrin and Perouse de Montclos (2018). Horizontal inequalities—differences (real or perceived) in access and opportunities across groups—can create grievances among disadvantaged groups, making countries more vulnerable to conflict (United Nations and World Bank 2018).

15 Vivekananda et al. (2019). Local evidence suggests that the ISWAP faction of Boko Haram has sought to fill social service provision gaps and foster income-generation opportunities to try to win over Lake Chad Basin communities and secure its position. According to community members and security sources, ISWAP has set up state-like structures in the Abadam, Kukawa, Guzamala, Marte and Monguno local government areas in Borno State, north-east Nigeria (Samuel 2019).

16 The report is also informed by World Bank (2003, 2013b, 2017).

17 For more information, see World Bank (2020b).

Figure 1.1: Analytical framework to identify opportunities to strengthen territorial development and address fragility in the Lake Chad region



Source: World Bank elaboration based on World Bank 2003, 2009, 2010, 2011, 2013b, 2017.

growth, stagnant poverty reduction, and low human development outcomes.[18] The policy framework (top and bottom of the figure) identifies policy options that can help strengthen territorial development and reduce FCV, helping the region break this vicious cycle.

Territorial development challenges are understood through three dimensions of economic geography, the three Ds: density, distance, and division. A low local *density* of economic production limits the efficient agglomeration of labor and capital and, thus, the potential for economic growth. Economic and physical *distance* to leading areas restricts the flow of capital, labor, goods, and services, and thus the opportunity for individuals and firms. Physical, sociocultural, ethnic, or other thick *divisions* and borders curb convergence in living standards, including through the unequal coverage of basic services and by hindering the spread of the benefits of growth.[19] Suboptimal development outcomes derived from low density, long distances, and thick divisions tend to exacerbate FCV challenges, low government capacity, and the scarcity of resources. These collectively create a negative feedback loop that leads to worsened development outcomes.

Territorial development challenges often intersect with challenges related to the two Cs—conflict and climate change—thus exacerbating the gap between lagging and leading areas. Areas with low economic density (insufficient agglomeration to foster economies of

18 Given data constraints, alternative variables may be used as a proxy to illustrate these indicators; e.g. using nightlights as a proxy of economic growth, living standards for poverty reduction and malaria incidence for human development to show how due to challenges and shocks these indicators deviate from their optimal trajectory.

19 While the inverse—active crossborder dynamics, trade and mobility—can be a factor of resilience.

scale in production) and high unemployment tend to be a fertile ground for illicit actives and violence.[20] Enforcing the rule of law in areas distant and disconnected from markets is also more difficult for governments that are limited in reach or lack relevant incentives. Violent conflict often leads to an overall increase in transaction costs, which raises physical and economic distance to markets. Divisions also aggravate distance. For example, differences in language, place of origin, and ethnicity are magnified by conflict over scarce resources and constitute strong barriers to internal migration.[21] Economic distance, meanwhile, limits economic opportunities and employment among a population, particularly among young people. This lowers the cost of engaging in illicit economic activities and violent behavior. Rebellion is often perceived to offer a viable living to followers who have no other source of livelihood.[22] Violent regions, for their part, tend to exhibit high levels of corruption, weak rule of law, and ineffective institutions, all of which make them less successful at attracting economic activity. This demonstrates the close link between violence and economic isolation. Shocks to the system, such as violent conflict arising from adverse environmental conditions because of human activity or from pandemics, can limit the flow of capital and labor, affecting income-generating activities and leading to lower growth and higher poverty rates.

Conflict and climate change pose challenges to household access to basic services and the ability of households to accumulate and use productive assets. Violent conflict in affected regions tends to interrupt public service provision or even render it impossible and typically leads to the depletion of household productive assets. It often also results in the forced displacement of people, including over national borders, and the deterioration of infrastructure, further interrupting access to services and the erosion of assets. The inability to use assets productively and to access services can deepen existing divisions and frictions among groups.

Fragility and conflict pose challenges for public and private investment. This increases economic distance and lowers economic density, leaving affected areas increasingly isolated.[23] Discrimination can likewise be reinforced by profound divisions, such as the social or political differences associated with persistent disparities in living standards. Unequal social and economic opportunities and the public perception of such inequality can adversely affect social cohesion by deepening grievances and feelings of exclusion and marginalization, which, if unaddressed, can lead to tensions and sometimes turn into violent mobilization. Additionally, climate change and harsh environmental conditions can limit opportunities in lagging areas, aggravating existing problems and perpetuating disparities. Lagging areas that face difficult climatic conditions, lack access to basic services, and experience poor governance in a region affected by insurgencies and conflict are often burdened by violence. Lagging regions—lacking access to basic services and the ability to use assets productively and subject to suboptimal economic and social development outcomes—are thus as much a driver as a consequence of FCV, in a vicious cycle that makes escaping the fragility trap difficult for countries.

Guided by this analytical framework, the next sections synthetize the previous literature and policy reports, while also drawing on original policy research prepared for this Regional Economic Memorandum that contribute new knowledge on the trends and drivers behind the region's low economic growth and high poverty rates.

20 Unemployment and idleness are cited as the most important factor motivating young people to join rebel movements in areas affected by violence, according to the 2011 Conflict, Security, and Development World Development Report. At the same time, the relationship between unemployment and violence has not been established as clearly through econometric analysis, likely due to poor data and/or because the link is indirect rather than direct (World Bank 2011).

21 World Bank (2009). A study of 11 Sub-Saharan countries showed that, while ethnicity was a strong predictor of differences in under-5 mortality, if combined with geography, it predicted the probability of survival among children (Brockerhoff and Hewett 2000).

22 World Bank (2011).

23 Isolation tends to result both in divided identity groups and in marginalization, as well as fewer economic opportunities. For example, the average GDP per capita of all landlocked developing countries is three-fifths that of their maritime neighbors (World Bank 2011).

1.3 Recent Socioeconomic Trends in the Lake Chad Region

1.3.1 Long-Term Demographics

Poverty rates, economic growth, and other core socioeconomic indicators in the Lake Chad Basin trail the indicators in other areas of the countries.

Population growth in the Lake Chad Basin countries is among the highest worldwide. The population of Cameroon, Chad, Niger, and Nigeria is forecast to double over the next 20 years. The Lake Chad region had an estimated increase in population by 14 million between 2000 and 2020.[24] While significant progress is being made in other regions of Africa, countries in the Lake Chad Basin are still lagging in the demographic transition. Indeed, the classic pattern of demographic transition—a significant decline in under-5 mortality leading to a sharp drop in fertility—has not yet unfolded in the Lake Chad Basin countries. The average number of children per woman in most Lake Chad Basin countries remains high, at close to or above five children per woman, with no signs of a significant decline.[25] Fertility rates are higher in the lake area than in the rest of the corresponding countries. For example, the areas of Cameroon and Nigeria that surround the lake present rates of 6.8 and 5.8 children per woman, respectively, compared with 4.8 and 5.3 children per woman in the rest of these two countries. In Niger's Diffa and Zinder regions, fertility rates are even higher, at 8.2 children per woman compared with 7.5 children per woman in other parts of the country. The Lac and Hadjer-Lamis regions of Chad are the exception: the average fertility rate is slightly lower than the average in other parts of the country (6.2 versus 6.5 children per woman, respectively).[26]

Some of the critical drivers behind demographic shifts in the Lake Chad region are related to climate and environmental factors. In the 1970s, the Sahel experienced severe droughts that strained the livelihoods of agriculturalists and pastoralists across a vast area. The droughts reduced water levels dramatically, dividing Lake Chad into two separate bodies of water, the northern and southern pools. By the 1980s, the water area had shrunk to 2,000 km^2 (from 25,000 km^2 in the 1960s). NASA satellite pictures reveal a clear deterioration in the lake's surface area, decreasing by approximately 82 percent since the 1960s (Map 1.3).[27] The droughts drove some people from the region to migrate toward the lake. Some moved to the lake's shore, but most chose to migrate to the numerous islands in the lake for their fertile farmland, fishing opportunities, and pastures.[28]

The historical population growth in the Lake Chad region is rapid, but not especially more rapid than in the other parts of the countries. An analysis of historical population census data tracking total and urban population patterns at a fine spatial level from the 1960s to the 2010s in three of the four Lake Chad Basin countries—Cameroon, Chad, and Niger—shows how demographic dynamics have shifted in areas near the lake.[29] A simple comparison of the annual population

24 World Bank calculations based on 2020 data of Population Counts (dashboard), WorldPop, University of Southampton, Southampton, UK, https://www.worldpop.org/project/categories?id=3.

25 See https://wcaro.unfpa.org/en/publications/demographic-dynamics-and-crisis-countries-around-lake-chad.

26 Data on total fertility rates come from the latest Demographic and Health Surveys available in each country: Cameroon, 2018; Niger 2012; Nigeria, 2018; and Chad, 2014.

27 It has been estimated that Lake Chad lost about 90 percent of its surface water area (around 23,000 sq. km) between the mid-1960s and the mid-1990s. While its water level has been slightly recovering since the mid-1990s, it is still on average 80 percent less than it was in the mid-1960s.

28 See Vivekananda et al. (2019).

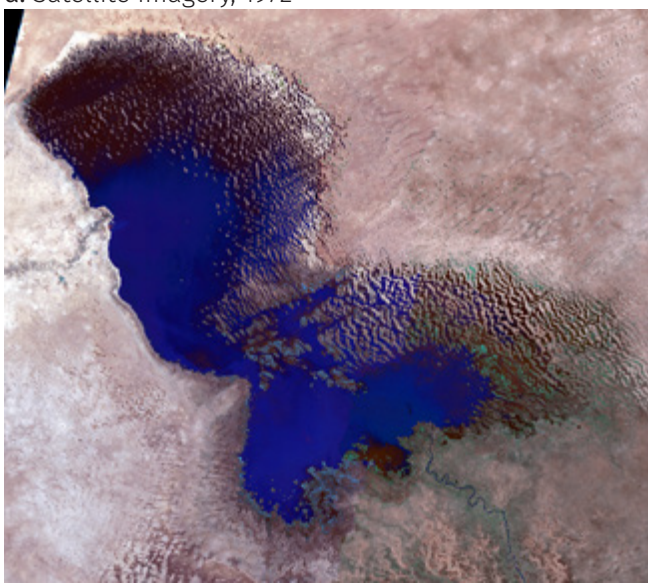
29 Nigeria was excluded from this analysis because of a long history of disputed census results. The results presented in this section are taken from Jedwab, Haslop, et al. 2021, technical paper for this report.

growth rate between the Lake Chad region and the other parts of the countries reveals that population growth in the two areas is roughly the same. In Cameroon, the annual rate of population growth in the Lake Chad region between 1956 (the earliest year of census data availability) and 2005 (the latest census year) is 2.8 percent, which is slightly lower than the rate in the rest of country (3.2 percent). In Chad, the annual population growth rate of the Lake Chad region between 1948 and 2009 (3.2 percent) exceeded the rate in the rest of the country (2.6 percent), whereas, in Niger, these numbers are roughly the same (around 3.5 percent for both the Lake Chad region and rest of the country between 1951 and 2017).

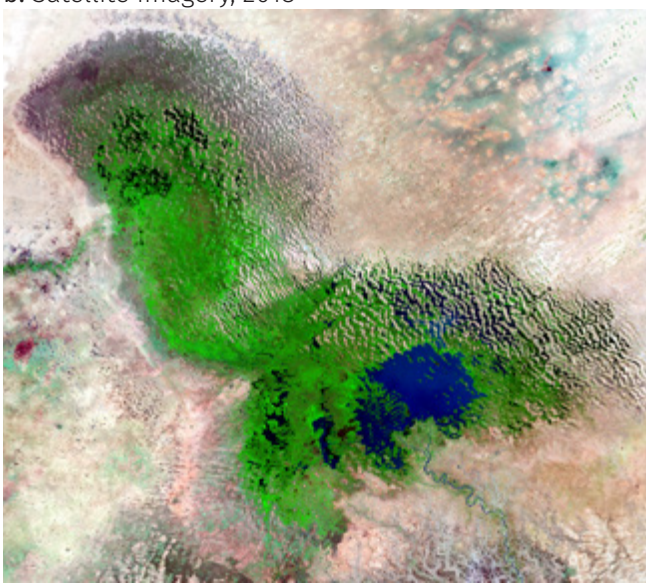
The shrinkage of Lake Chad between the 1960s and mid-1990s—the level has been recovering since then—posed downward pressure on population growth in areas proximate to the lake. This effect was particularly pronounced in Cameroon and Niger, where areas close to the lake saw as much as a 40 percent relative slower growth in population. One explanation for this

Map 1.3: The evolution of Lake Chad

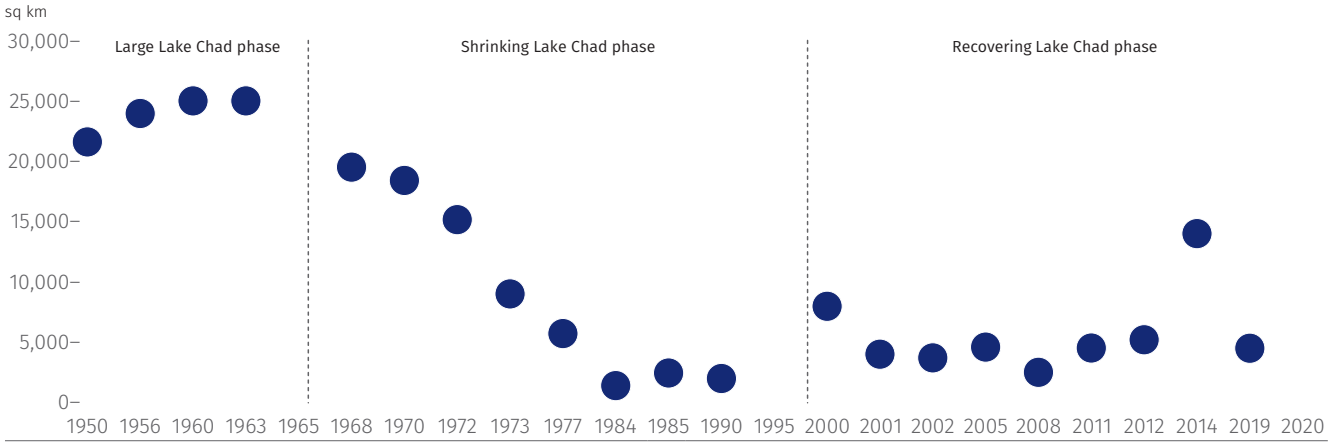
a. Satellite imagery, 1972



b. Satellite imagery, 2018



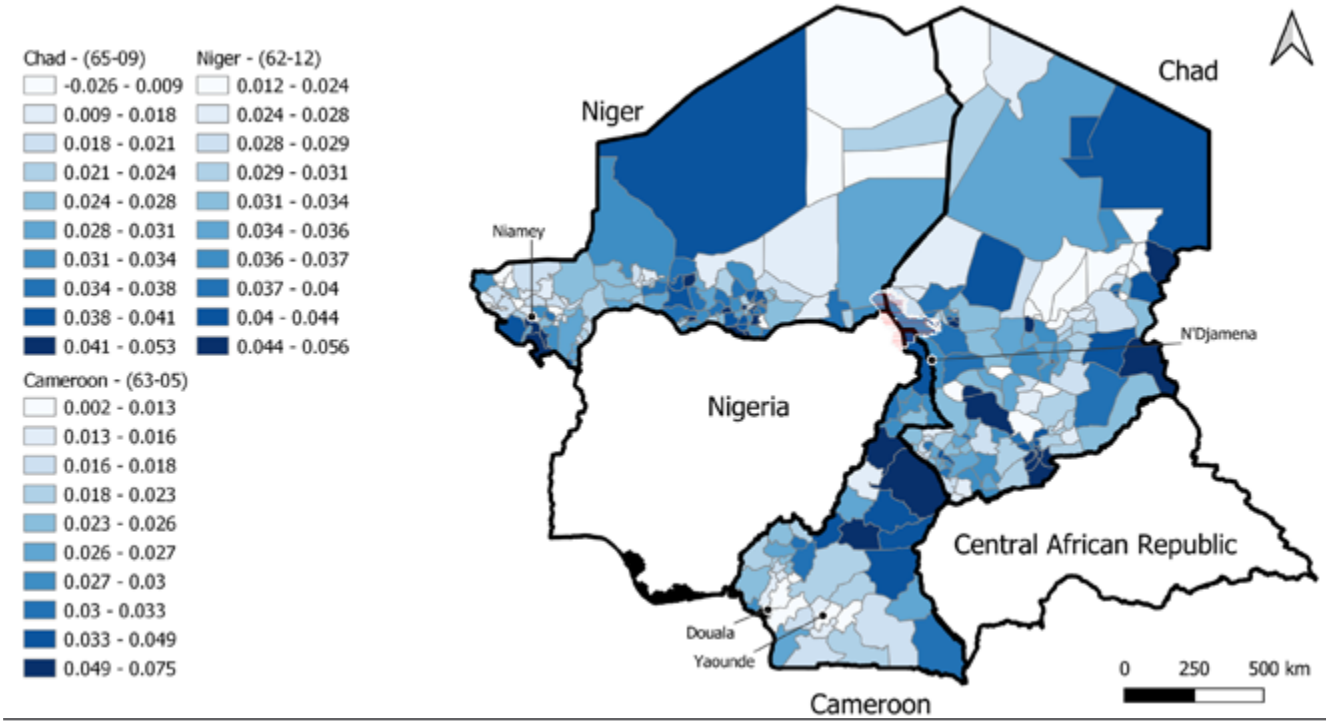
c. Total water surface, 1950–2020



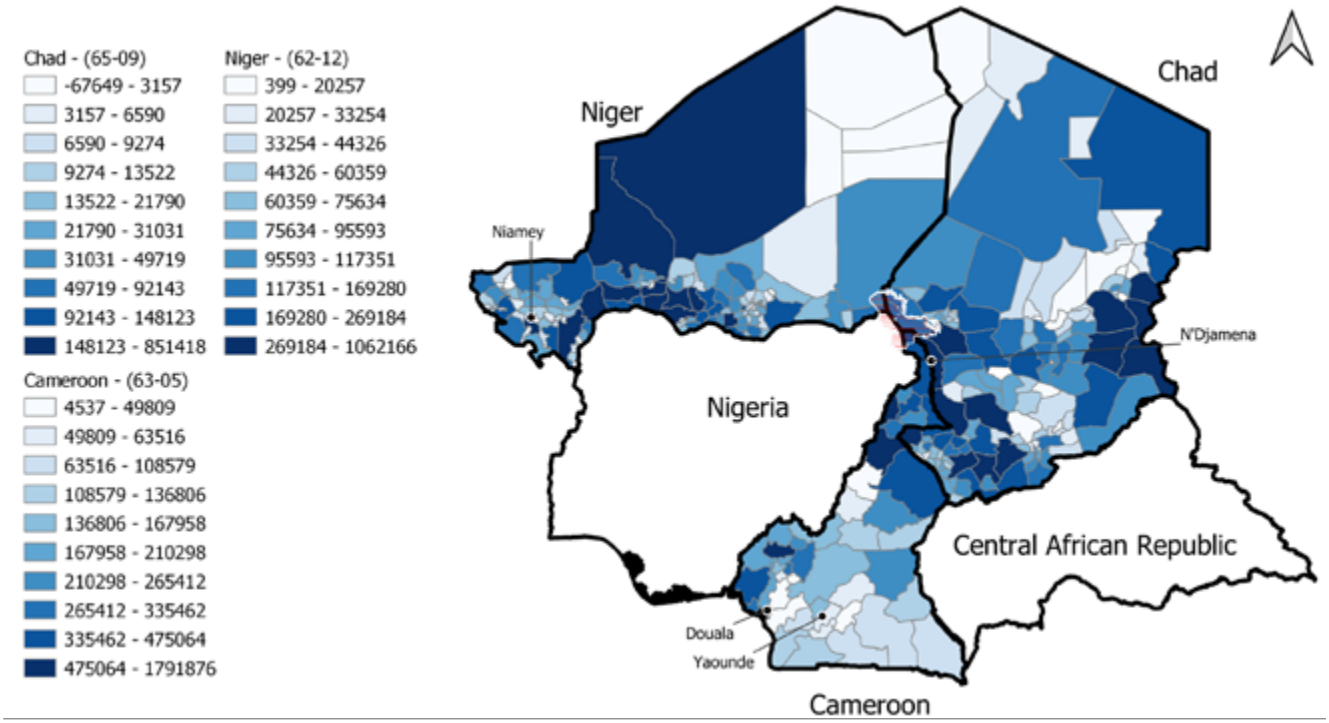
Sources: Panels a and b: UNEP/DEWA/GRID Geneva, based on NASA's satellite images. Panel c: Olivry et al. 1996; Šedick, no date; FAO 2009; LCBC 2015; Okpara et al. 2016; Ighobor 2019.

Map 1.4: Historical map of population growth, Lake Chad Basin countries, 1950s–2010s

a. Annual growth rate in population



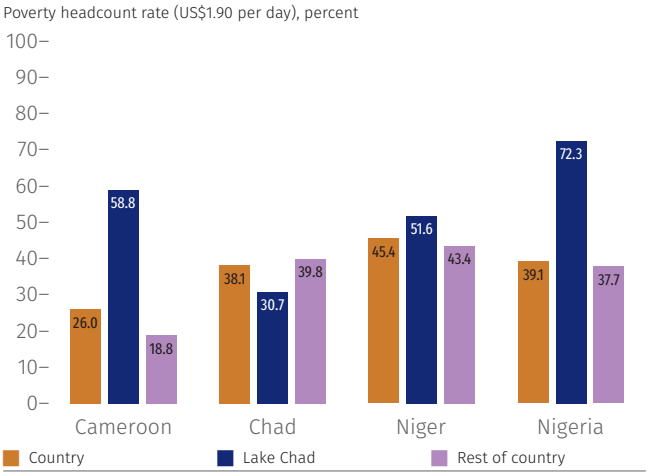
b. Absolute change in population



Source: Jedwab, Haslop, et al. 2021, technical paper for this report.
Note: This figure shows the annual population growth rate and absolute change in the size of population by historically consistent subdistrict boundaries reconstructed for Cameroon, Chad and Niger. Nigeria is not included because of data limitations. These three countries are divided into 113, 138, and 119 subdistricts, respectively. Lake Chad is shown in the center of the map.

relationship may be the loss in economic opportunities. As the water level receded between the 1960s and the mid-1990s, the lake shore moved farther from cultivated land, increasingly limiting irrigation possibilities. A smaller lake also reduces incomes in fishing communities. It can likewise impact cattle herding (requiring proximity to the water and vegetation around the lake), an important sector in the Lake Chad region, where herders typically sell their cattle to urban markets in Nigeria. Recent years have seen signs of the lake water level resurging from its lowest level (roughly 2,000 km^2) in the 1990s to roughly 14,000 km^2. It remains to be seen whether this resurgence in the water level will attract more people into the basin areas by generating new economic opportunities.[30]

Figure 1.2: Poverty is more severe in the Lake Chad Basin than in other parts of the countries



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: Data on poverty are based on the latest household surveys conducted in Cameroon (2014), Chad (2011), Niger (2014), and Nigeria (2018). Rest of country = outside the Lake Chad region; LCB = within the Lake Chad Basin region.

1.3.2 Trends in Poverty Reduction

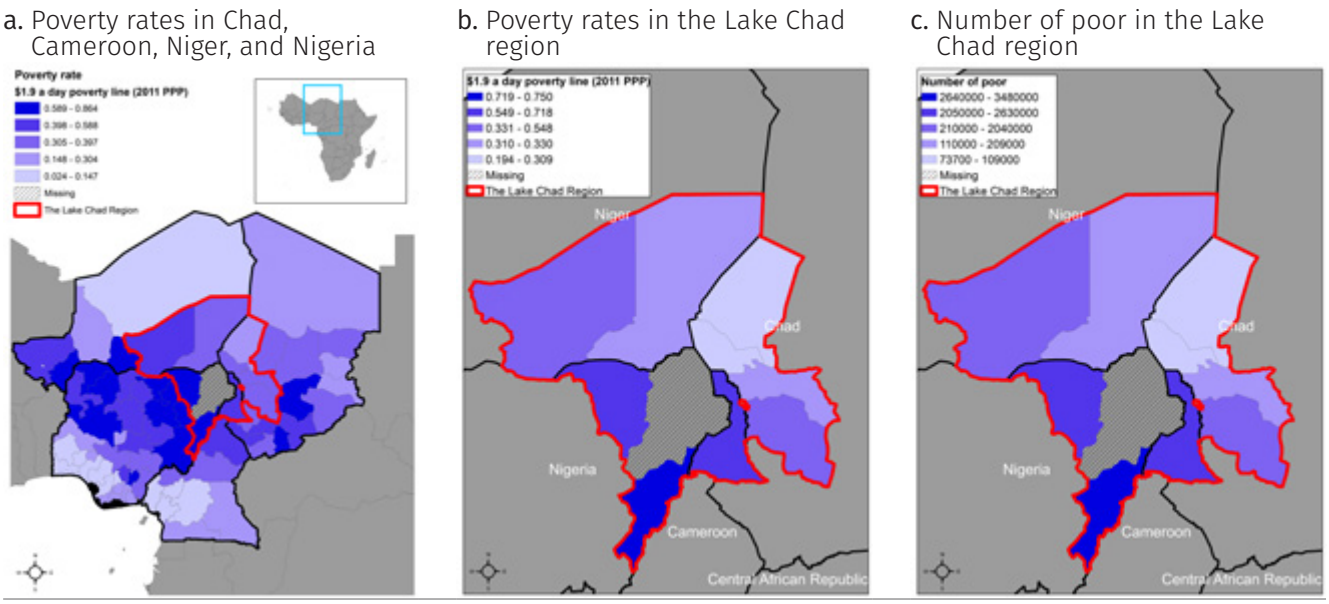
Given its high poverty rate, low human capital, and poor access to key services, the Lake Chad region is characterized as a lagging region. An analysis of the most recent household surveys available for each country shows that households in the Lake Chad region are poorer compared with households in neighboring regions (Figure 1.2).[31] The regional poverty rate in the Far North Region of Cameroon (59 percent) is three times higher than the rate in the rest of the country (19 percent). In Nigeria, the poverty rate in the Lake Chad region (72 percent) is nearly twice as high as the rate in the rest of the country (38 percent); part of this spatial gap is likely explained by the devastating impact of the Boko Haram conflict in Nigeria's North East.[32] Chad is the only exception. There, the poverty rate in the country's Lake Chad region (31 percent) is lower than the rate in the rest of the country (40 percent).[33] This is explained by the fact that the areas in Chad around the lake are near the capital of the country, with a consequently higher urbanization rate and a relatively high population density.

There is also a significant spatial gap in poverty *within* the Lake Chad region. Poverty is most prevalent in the parts of the Lake Chad region that lie within Nigeria. The poverty rates in Adamawa and Yobe states reach as high as 74 percent and 70 percent, significantly higher than the national average of 38 percent (Map 1.5, panel b). These regions are also home to the largest number of the poor in the Lake Chad region (Map 1.5, panel c). Kanem Region in Chad has the lowest poverty rate (19 percent) across the Lake Chad region.

Not only is the level of poverty high in the Lake Chad region relative to the other parts of the countries, but the pace of poverty reduction in the region is slow. There is little sign that the spatial gap in poverty between the Lake Chad region and neighboring regions is narrowing. In Cameroon, for instance, poverty declined by 4 percent in the Far North Region compared with a 6 percent decrease in the rest of the country between 2007 and 2014. While Niger as a whole saw a reduction in poverty from 51 percent to 45 percent between 2011

30 Vivekananda et al. (2019).
31 The results presented in this section are drawn from Masaki and Rodríguez-Castelán (2021), technical paper for this report.
32 The country's Borno state is excluded from the analysis given that there is no representative household survey for that state.
33 Mahmood and Ani (2018).

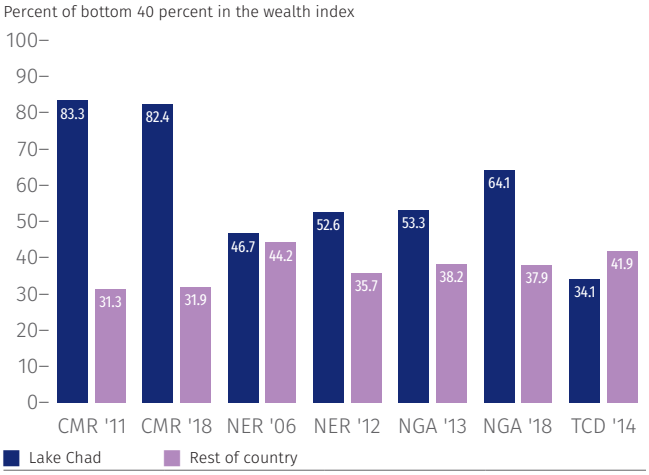
Map 1.5: Poverty in the Lake Chad region



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: Data are based on the latest household survey in Cameroon (2014), Chad (2011), Niger (2014), and Nigeria (2018). Poverty rates are calculated at US$1.90 per day (2011 purchasing power parity). Borno State is excluded given that there is no representative household survey for that state for security reasons.

and 2014, the Lake Chad region in Niger experienced a slight *increase* in poverty, from 48 percent to 52 percent. This pattern of nonconvergence in welfare and poverty is corroborated by data on the ownership of assets and how they have changed in the Lake Chad region. The share of households that are relatively asset poor—or in the bottom 40 percentile of asset wealth distribution in a given survey by country and year (the bottom 40)—shows no clear sign of convergence between the Lake Chad and non–Lake Chad areas of each country (Figure 1.3).[34] For instance, in Niger and Nigeria, the share of asset-poor households increased in the Lake Chad region, while, in Cameroon, the share remained almost unchanged between the two latest rounds of the Demographic and Health Surveys. These findings suggest that wealth gaps between the Lake Chad region and the rest of the countries may have worsened.

Figure 1.3: Asset deprivation in the Lake Chad Basin versus other parts of the countries



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: Data based on the latest two rounds of Demographic and Health Surveys in each country. CMR = Cameroon. TCD = Chad. NER = Niger. NGA = Nigeria. The year refers to the year the survey was conducted.

34 The wealth index was constructed for the latest two Demographic and Health Surveys in each of the Lake Chad Basin countries. Our wealth index is a composite measure of various household assets, including housing materials, access to electricity, cooking fuel, access to improved water, as well as ownership of various items such as televisions and bicycles. We applied a principal component analysis to generate the composite index. To make our wealth index comparable over time within the same country, we applied the same coefficients for use as weights across the two latest surveys. "Asset-poor" households refer to those households whose wealth index score is in the bottom 40 percent of distribution for the given survey country/year.

Food insecurity is also an increasing concern in the region. Undernourishment tends to be driven by escalating conflict and competition over natural resources and by climate change and environmental degradation spurred by population growth. The Lake Chad Basin was recently characterized as one of three major food insecure hotspots in West Africa, where food insecurity is on the rise after having declined for several years, according to a World Bank and FAO report.[35] Between 2014 and 2019, the number of undernourished people in West Africa rose from 32 million to 56 million (that is, from 10 percent to 15.2 percent of the population). The highest numbers were found in northern Nigeria (5.0 million), Cameroon (1.4 million), and Niger (1.4 million). The United Nations Office for the Coordination of Human Affairs puts the number of people facing crisis and emergency levels of food insecurity in Nigeria's North East at 4.3 million, and 500,000 children are at risk of severe malnutrition.[36] Food insecurity is likely increasing because of COVID-related impacts. Five million more people were acutely food insecure in West Africa in 2020 during the lean season between June and August, compared with the five-year average, that is, 17 million versus 12 million people, respectively).[37] Between March and May 2021, 19.6 million people required immediate food assistance.

1.3.3 Local Economic Dynamics

In addition to lagging in terms of core poverty indicators, the Lake Chad region has experienced little economic progress over the past three decades. An analysis of local economic growth based on nighttime light intensity—which serves as a useful proxy for capturing both the size of local economic activities and the change in this activity over time—shows that the intensity of nighttime light is strongly correlated with the distribution of people and economic activity (Map 1.6, panel a).[38] Overall, nighttime light grew more quickly in areas that appear to be more densely populated or characterized by higher levels of economic activity (as indicated by nighttime light), particularly in Nigeria's North Central and South West (Map 1.6, panel b).

Seen from space, the regions near Lake Chad in Cameroon and Nigeria exhibit a relatively low level of luminosity and lower rates of growth. The gaps in the intensity of nighttime light between the Lake Chad region and other parts of the countries are particularly stark in Cameroon and Nigeria, whereas, in Chad and Niger, the average intensity of nighttime light is slightly higher in the Lake Chad region (Map 1.6, panel c). The annual rate of growth in nighttime light is also slower in the Lake Chad region compared with other parts of Cameroon and Nigeria. This implies that there has been no substantial regional growth in the areas around the lake. In Nigeria, in particular, increases in the intensity of nighttime light between 1992 and 2013 were much slower in the Lake Chad region compared with the rest of the country (Map 1.6, panels c and d).

1.3.4 Human Capital Outcomes and Access to Basic Services

In addition to monetary poverty indicators and economic growth, the Lake Chad region lags in key human capital indicators.[39] The literacy rate (ages 15 or more) and the completion rate in primary education (ages 14–25) are significantly lower in the Lake Chad region compared with the national average (Figure 1.4). Child health conditions in the region are also grim. For instance, child stunting is roughly 10 percent–15 percent higher in the Lake Chad region compared with other

35 The other two areas are the Central Sahel and eastern Mauritania (World Bank and FAO 2021).

36 OCHA (2020).

37 World Bank and FAO (2021).

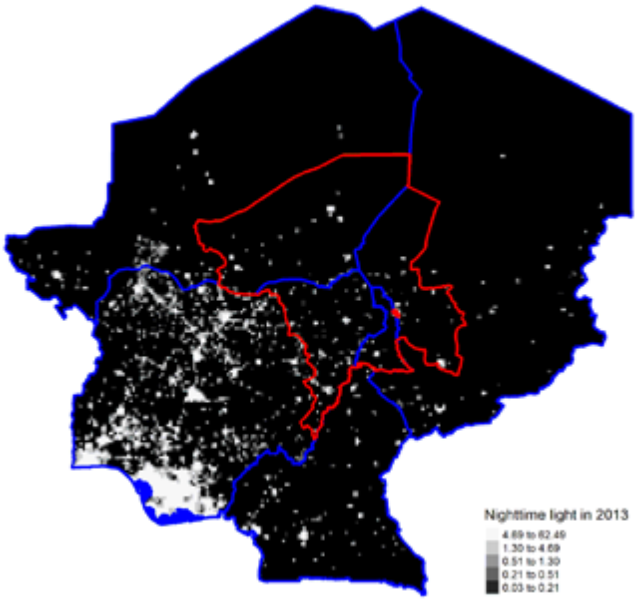
38 The analysis of nighttime light relies on Defense Meteorological Satellite Program–Operational Line-Scan System data that are intercalibrated by Li et al. (2020), allowing for a better comparison over time. The intensity of nighttime light is measured in a digital number ranging from 0 and 63 that represents an average of lights in all nights after sunlight, moonlight, aurorae, forest fires, and clouds have been removed algorithmically, leaving mostly human settlements.

39 The results presented in this section are drawn from Masaki and Rodríguez-Castelán (2021), technical paper for this report.

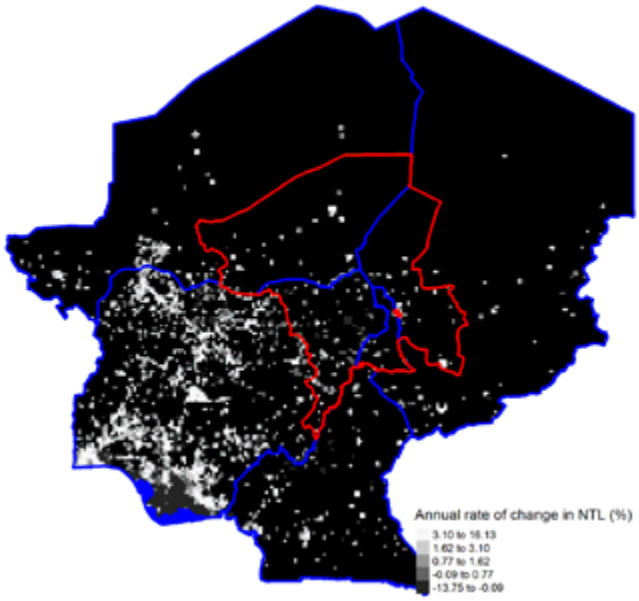
parts of the countries (see Appendix 1.A, Table A1). Based on original analysis performed for this report, these results are in line with other studies. For example, according to the International Crisis Group, the gross school enrolment rate in the lake area of Chad is below 30 percent, and community teachers (largely the parents of pupils) generally stand in for trained teachers.[40] In the Chadian part of the lake, there is only one doctor for every 140,000 inhabitants, that is, a quarter of the national average.[41] The low access and quality of education, health

Map 1.6: Growing economic gap, Lake Chad region and rest of the countries, 1992–2013

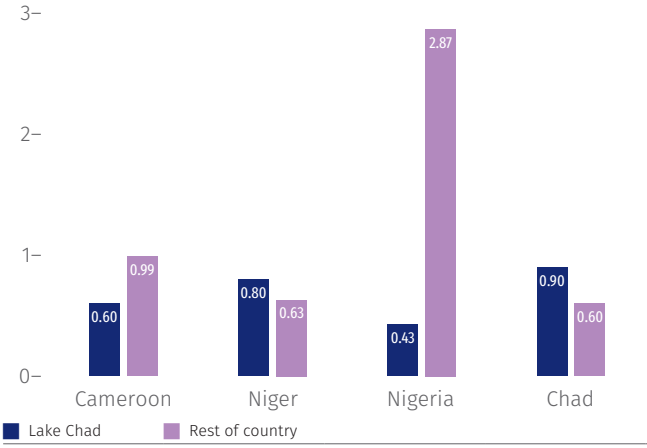
a. Nighttime light intensity, 2013



b. Annual change, nighttime lights, 1992–2013

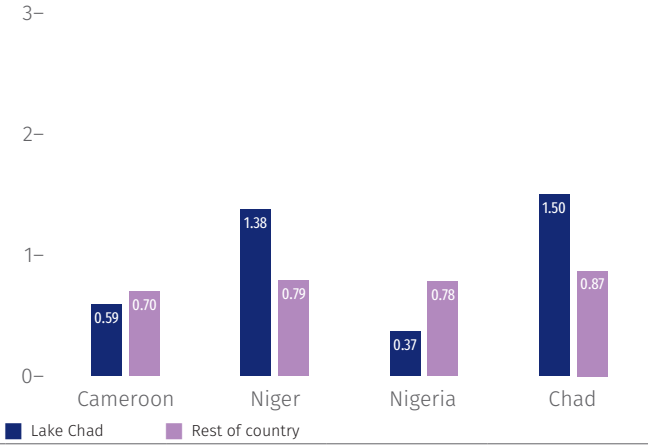


c. Nighttime light intensity, 2013



d. Change in nighttime lights

Annual rate of change, 1992–2013, percent



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: Panel a shows the mean of nighttime luminosity in 2013 based on stable Defense Meteorological Satellite Program intercalibrated nighttime lights data (Li et al. 2020) at a spatial resolution of 10 kilometers. Panel b shows the annual rate of growth in the mean of nighttime luminosity between 1992 and 2013 in percent. Panels c and d show the mean of nighttime luminosity and the annual rate of change in nighttime luminosity in percent during the same time period. The calculations for panels c and d were performed only on a subset of grid cells that are lit (with a positive value in digital number at some point between 1992 and 2013) thus excluding areas that are largely rural and unpopulated.

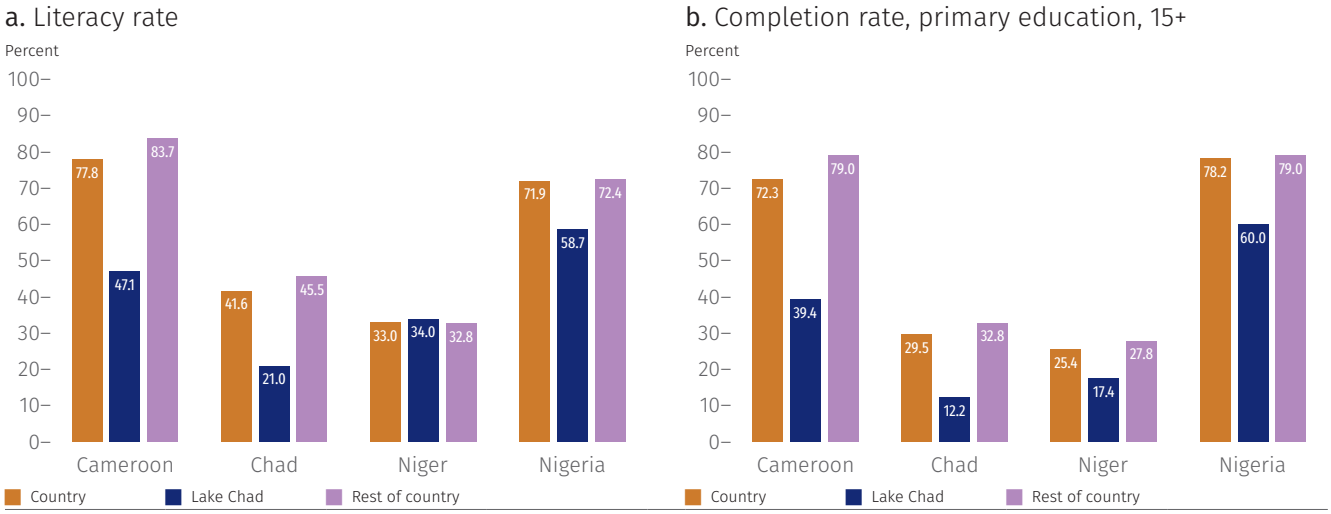
40 ICG (2017).

41 ICG (2017). The figure for Chad is much lower than in Cameroon's Far North region (1/52,000) or Niger's Diffa region (1/24,500), both close to the lake.

care, and other services in the region has been aggravated by the erosion of infrastructure, both public and private, resulting from the conflict.[42]

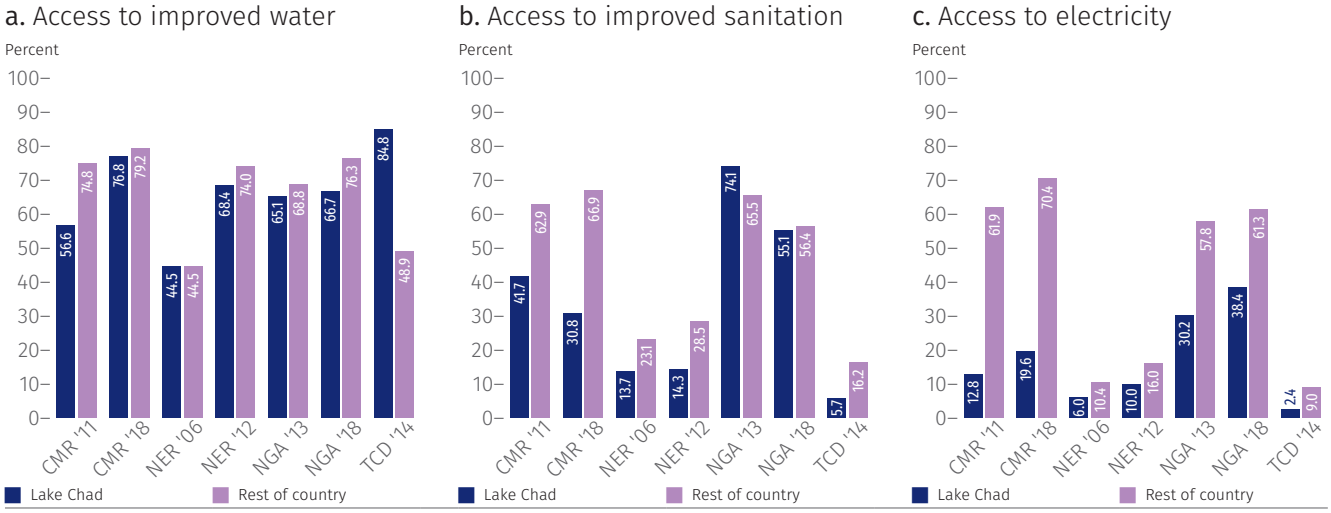
Access to core public services in the Lake Chad Basin is also among the lowest in the area. The national average rate of access to electricity in Cameroon, Chad, Niger, and Nigeria is 62 percent, 8 percent, 14 percent, and 59 percent, compared with an estimated 20 percent, 2 percent, 10 percent, and 38 percent in the Lake Chad region, respectively. The Lake Chad areas of Cameroon and Chad suffer from lower levels of access to improved

Figure 1.4: Literacy and primary school completion rates are lower in the Lake Chad region



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: Data on poverty are based on the latest household surveys conducted in Cameroon (2014), Chad (2011), Niger (2014), and Nigeria (2018). Rest of country = outside the Lake Chad region.

Figure 1.5: Access to core public services in the Lake Chad region



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: The figure shows the percentage of households with access to improved water and sanitation and electricity. Data on access to these core public services are taken from the two latest Demographic and Health Surveys in each country. CMR = Cameroon. TCD = Chad. NER = Niger. NGA = Nigeria. The year is the year in which the survey was conducted.

42 It is reported that, during the armed group's eight-year rebellion, almost 1,400 schools have been destroyed in Borno and more than 57 percent of schools are unable to open because of damage or being in areas that remain unsafe (Al Jazeera 2017). Regarding health facilities: "Insurgents have destroyed about 788 health facilities in the region. In Borno 48 health workers have been killed and over 250 injured. The state has lost up to 40 percent of its facilities and only a third of those left in Borno state remain functional," (Obi and Eboreime 2017).

water and sanitation facilities compared with other parts of the countries (Figure 1.5). This gap is particularly pronounced in Cameroon, where the rate of access to improved water and sanitation is, on average, about 36 percent lower in the Far North Region than in the rest of the country.

There are also signs of a *widening* gap between the Lake Chad region and the rest of the surrounding countries in access to improved sanitation and electricity. In Cameroon, the share of households with access to improved sanitation in the Lake Chad region declined from 42 percent to 31 percent between 2011 and 2018, whereas the rest of the country experienced a modest improvement (from 62 percent to 67 percent) over the same period. A similar divergence pattern emerges in Nigeria, where access to improved sanitation in the Lake Chad area decreased from 74 percent to 55 percent between 2013 and 2018, a more rapid rate of decline than in the rest of the country (where access fell from 66 percent to 56 percent). Progress in expanding access to electricity in the Lake Chad region has also stagnated. In Niger, the regions of Diffa and Zinder saw access to electricity improve by 4 percentage points (from 6 percent to 10 percent) between 2006 and 2012, a slightly lower increase than in the rest of the country (where access improved by nearly 6 percentage points, from 10.4 percent to 16.0 percent) (Figure 1.5).

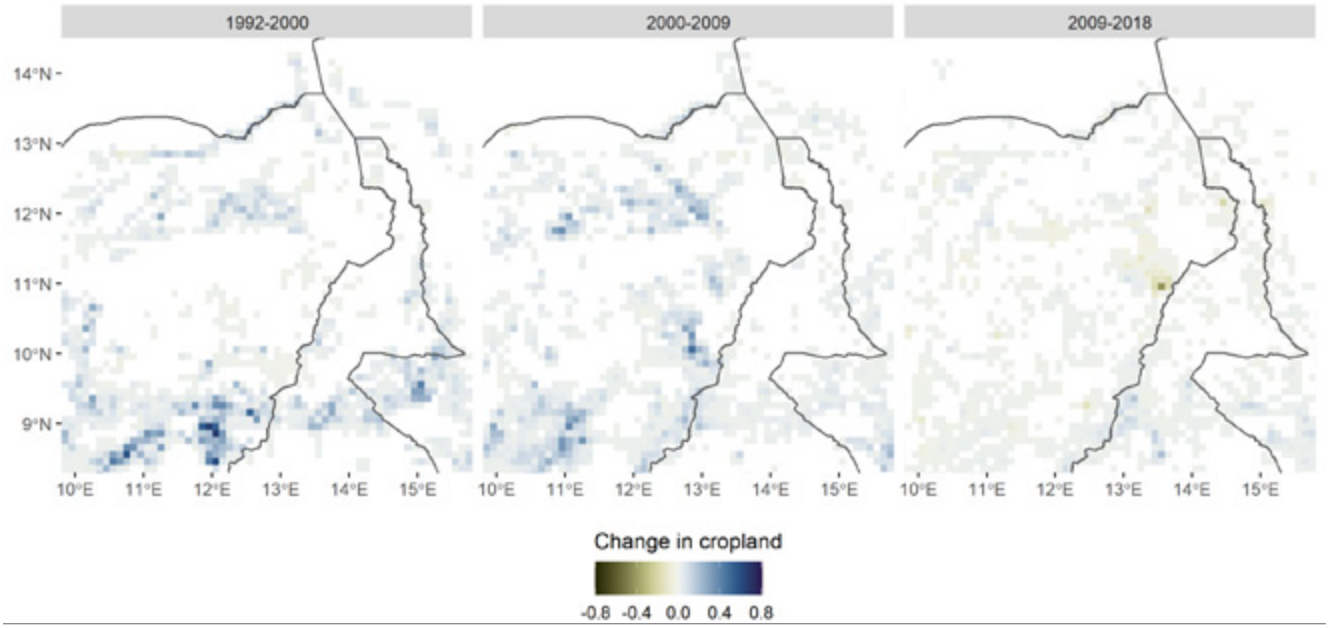
1.3.5 Trends in Agriculture

Agriculture constitutes the main sector of economic activity in the Lake Chad region. According to the latest household expenditure survey available in each country, the primary sector (agriculture, cattle herding, and fishing) accounts for about three-fourths of employment in areas near Lake Chad (Figure 1.9). Agriculture also generates significant indirect employment in related activities such as trade, transport, and manufacturing (for example, food processing, leather industry, brewing).[43] The main crops produced in the Lake Chad area include subsistence crops (cassava, millet, rice, sorghum, and onions) and cash crops (cotton, groundnuts). Red peppers are also an important cash crop along the Yobe River in Niger. Most of the farming in the Lake Chad Basin is rainfed, harvested by hand, and cultivated without the use of fertilizers and other agrochemicals. Millions of people—particularly in Cameroon, Chad, and Niger—depend on the lake for most of their economic activities and livelihoods. The resulting pressure on the soil and the depleting water resources pose serious sustainability problems for these activities.[44] At the same time, rather than a homogeneous market, agriculture in the region is a complex sector, encompassing both farming and herding. The two modes of production sometimes compete over resources and land. The competition over land between farmers and herders is often cited as a source of conflict, which is exacerbated by climate change and the lack of land rights. Tenure insecurity can limit access to land, investment in agriculture, and productivity. The limited capacity of local customary and informal mechanisms of enforcement of land rights across the region do not appear to be sufficient to cope with competition among farmers and herders.[45] It is estimated that, in 2018, there were more than 1,800 deaths across Africa from transhumance-related conflict associated with the added pressures on access to land.[46]

The Lake Chad region has seen an increase in arable or cropland areas over the past two decades, although recent years have seen a slight decline. According to an analysis of geospatial data from the European Space Agency,[47] the annual growth rate of cropland area inside the study area near Lake Chad in the four countries started at 0.31 percent during 1992–2000, fell to 0.24 percent

43 UNEP (2004).
44 Odada et al. (2005).
45 World Bank and FAO (2021).
46 Skah and Lyammouri (2020).
47 The results presented in this section draw on Blankespoor (2021), technical paper for this report.

Map 1.7: Trends in cropland area: 1992–2000, 2000–09, and 2009–18



Sources: Blankespoor 2021, technical paper for this report; data of ESA 2017.

during 2000–10, and was slightly negative during 2010–19. The annual growth rate of cropland area outside the study area in the four countries started at 0.48 percent during 1992–2000, fell to 0.33 percent during 2000–10, and was slightly positive during 2010–19 (Map 1.7). Irrigated areas represented only about 5 percent of the cropland area inside the study area and about 3 percent of the cropland area outside the study area between 1992 and 2019. The poor quality of irrigation—exacerbated by the variability in the level of the lake and the associated water resources as well as by the intensification of conflict leading to the destruction of irrigation systems—has made agricultural productivity in the region particularly vulnerable to erratic rainfall patterns and climate change.[48]

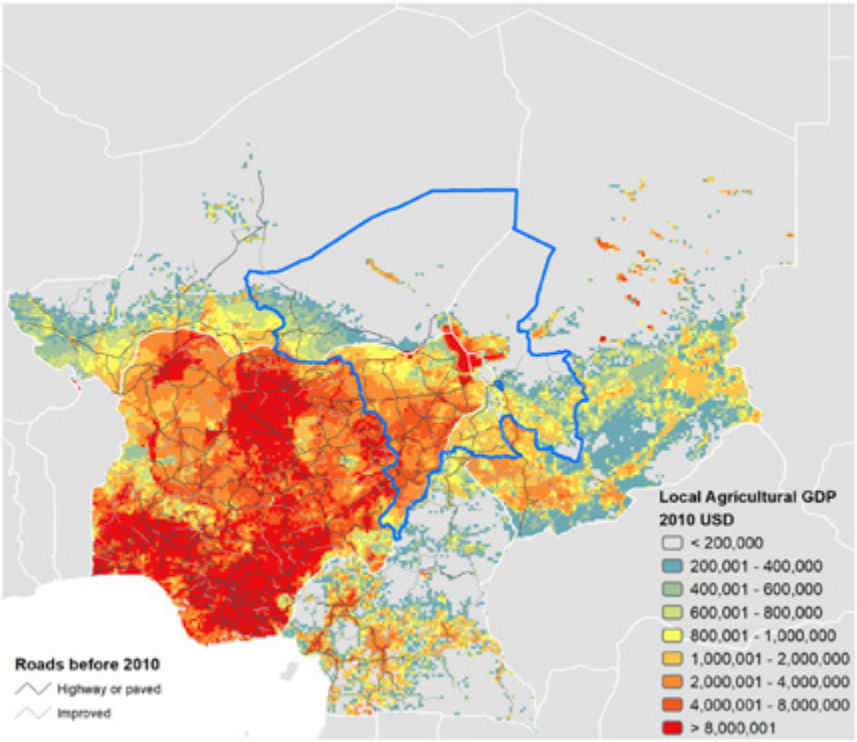
Most of the agricultural production within the Lake Chad region is spatially concentrated in the three states of Adamawa, Borno, and Yobe in Nigeria's North East. Map 1.8, panel a, illustrates the distribution of subnational agricultural gross domestic product (GDP) circa 2010, which is derived using a data fusion method based on cross-entropy optimization that disaggregates administrative level agricultural GDP into grids depending on satellite-derived indicators of the components that make up agricultural GDP, namely, crop, livestock, fishery, hunting, and timber production.[49] The level of agricultural GDP in Nigeria is considerably higher compared with the other three Lake Chad Basin countries. Patterns of agricultural production also differ significantly within the Lake Chad region by crop. For instance, cotton production is spatially concentrated in Adamawa in Nigeria and the Far North Region in Cameroon (panel b), whereas millet and sorghum production is more common in southern Niger and northern Nigeria (panel c) and in northern Nigeria and Cameroon's Far North (panel d), respectively. For the four countries, panel e illustrates dominant livelihoods with similar patterns considering how people gain access to food and income as well as markets. The northern areas of Chad and Niger are sparsely populated, with activities including salt, dates, and trading activities in oases along with nomad pastoralism and transhumance.

48 FAO (2016).

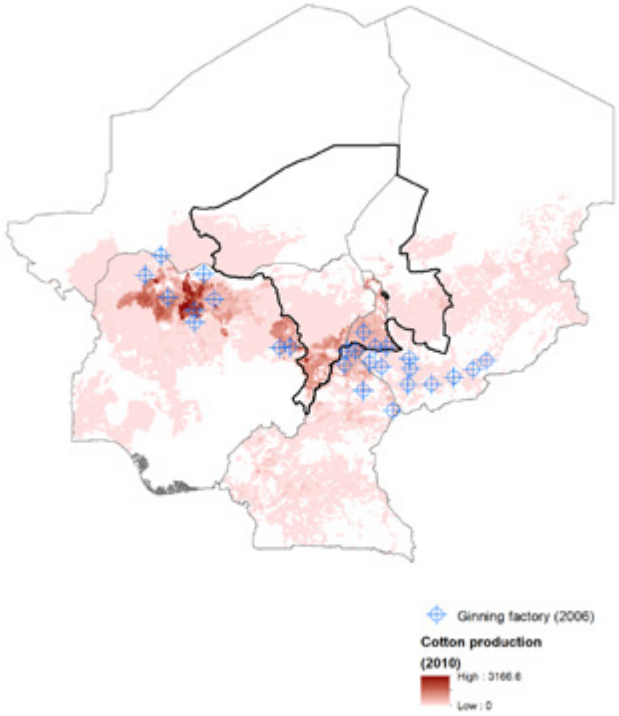
49 For more details on the methodology, see Blankespor et al. (2021).

Map 1.8: Agricultural activities in the countries of the Lake Chad Basin

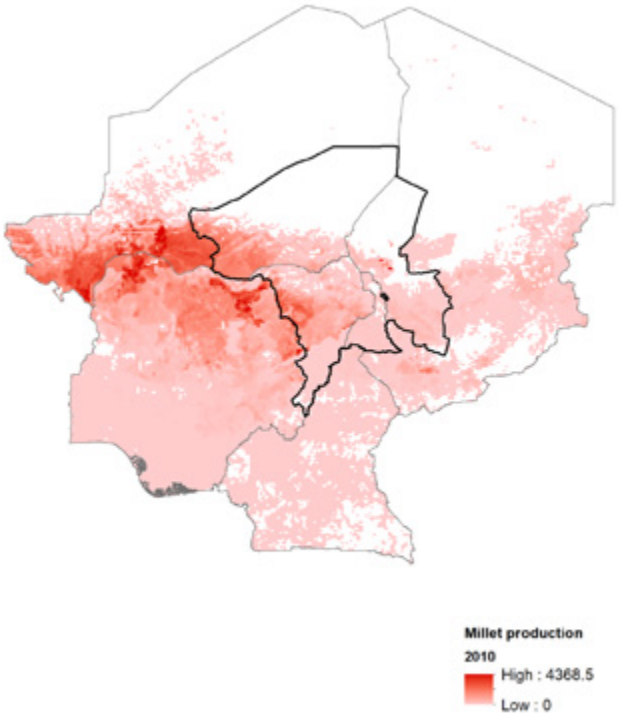
a. Agricultural GDP estimates



b. Cotton production

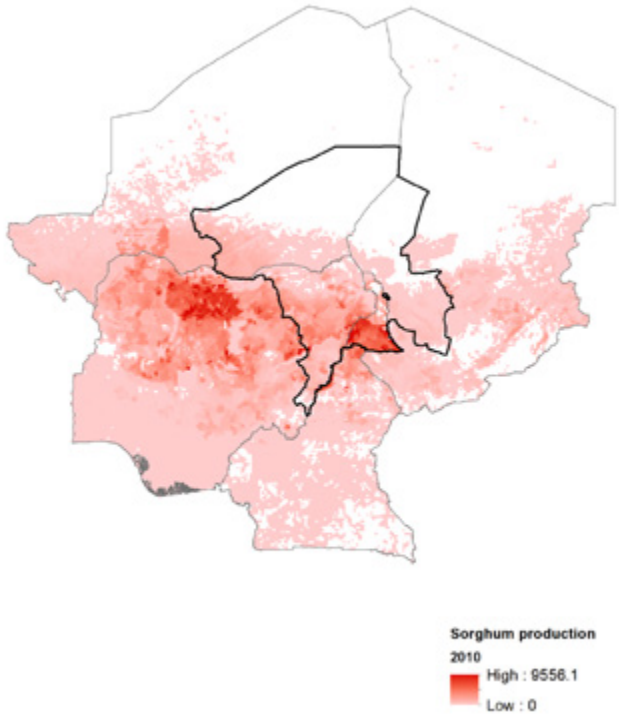


c. Millet production

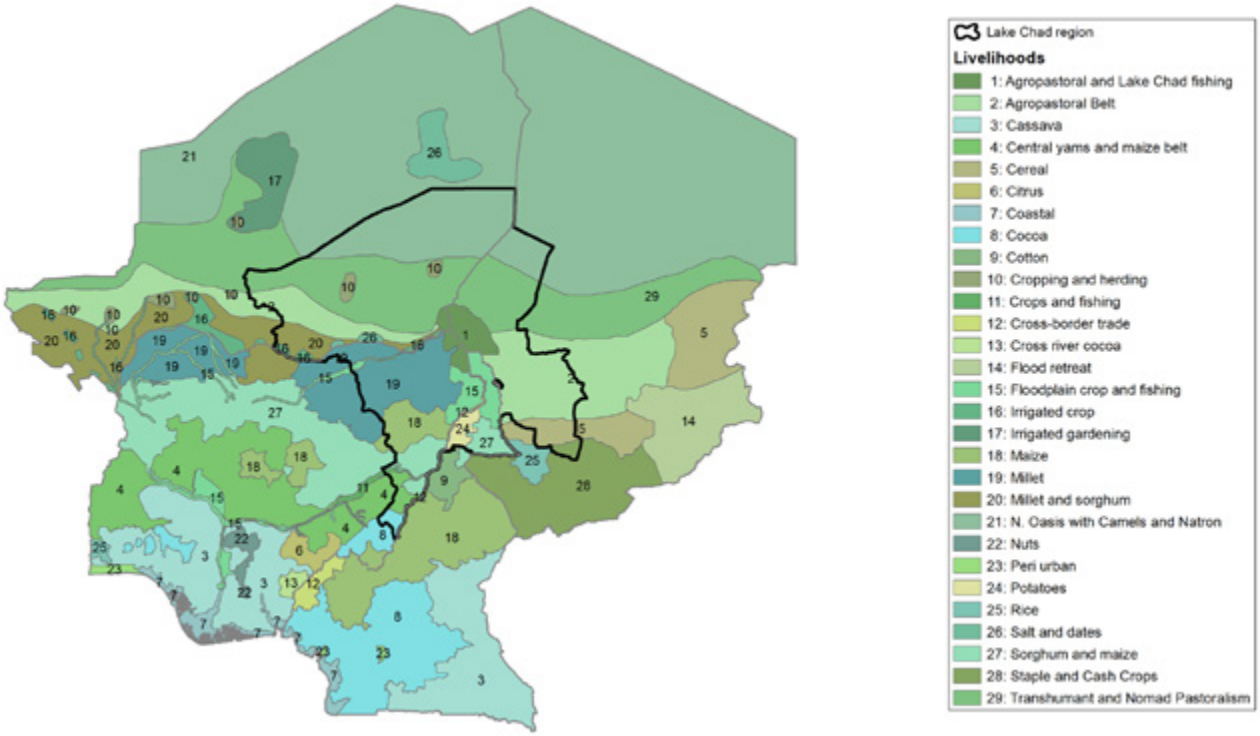


Map 1.8: Agricultural activities in the countries of the Lake Chad Basin (continued)

d. Sorghum production



e. Livelihoods



Sources: Blankespoor 2021, technical paper for this report. Data of Blankespoor et al. 2021; FEWS NET (Famine Early Warning Systems Network) (dashboard), Washington, DC, https://fews.net/; Yu et al. 2020.

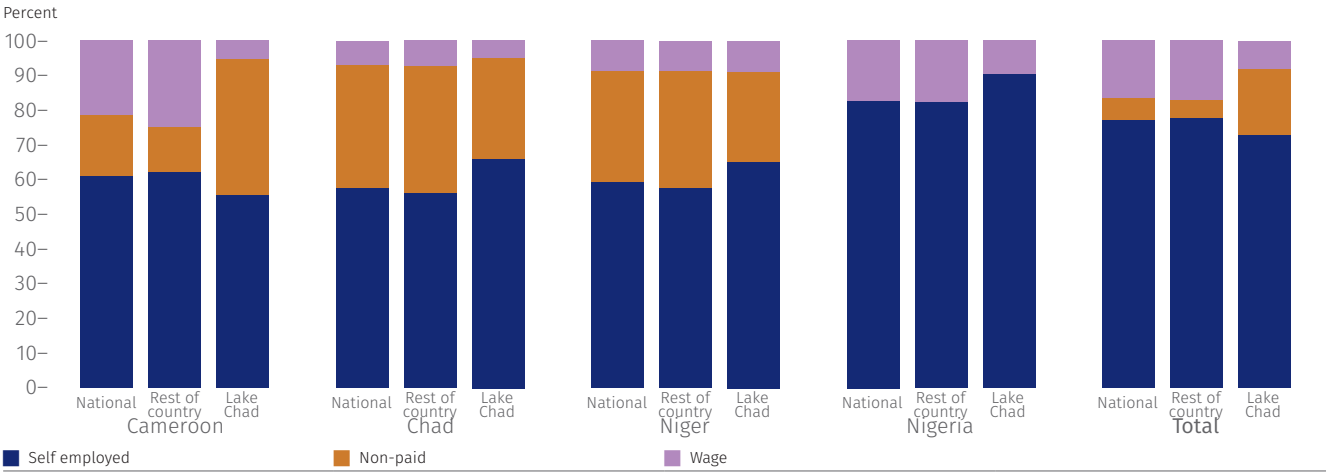
An agropastoral belt with millet and sorghum is located in southern Niger, where most of the population lives. Northern Nigeria has cultivated areas with diverse crops, including millet and sorghum as well as livestock. The area nearby Lake Chad includes flood retreat cultivation and fishing activities. This belt has relatively higher local crop production value and contributes over US$1 million in local agricultural GDP (2010 US dollars).

1.3.6 Jobs and Labor Market Composition

The labor market in areas near Lake Chad is predominantly characterized by poor jobs—that is, self-employment and informal work. The overall employment rate among working-age individuals is high in the Lake Chad region, averaging 71 percent, compared with 72 percent in areas outside the lake basin. Men are more likely to be employed (82 percent) than women (60 percent). However, most working-age individuals hold relatively lower-quality jobs that are largely characterized by self-employment (particularly farm self-employment) and unpaid employment. Wage employment is particularly limited across the Lake Chad region, only accounting for 8 percent of jobs, versus twice that rate (17 percent) in areas outside the lake basin. In the Lake Chad area in each country, wage jobs make up 5–10 percent of workers, from the lowest share in Chad (5 percent) to the relatively larger rate in Nigeria (10 percent) (Figure 1.6). Nonremunerated employment is also prominent in the region, representing 19 percent of jobs in the Lake Chad area of the four countries.[50]

Wage employment among women is particularly limited in the Lake Chad region. The gap in the quality of jobs is exacerbated by sex. At the national level, 11 percent of women have wage employment compared with 22 percent of men in the four basin countries (Figure 1.7). In the Lake Chad region, the share of women who have wage employment is one-fourth that of men (3 percent versus 12 percent, respectively). At the country level, the largest gap in wage employment is in Cameroon, where 2 percent of women have wage employment in the areas near Lake Chad, compared with 15 percent of women in the rest of the country (Figure 1.7). The share of wage employment among men is also lower in the Cameroonian Lake Chad region (9 percent) compared with other parts of the country (34 percent). Overall, wage employment is skewed toward men.

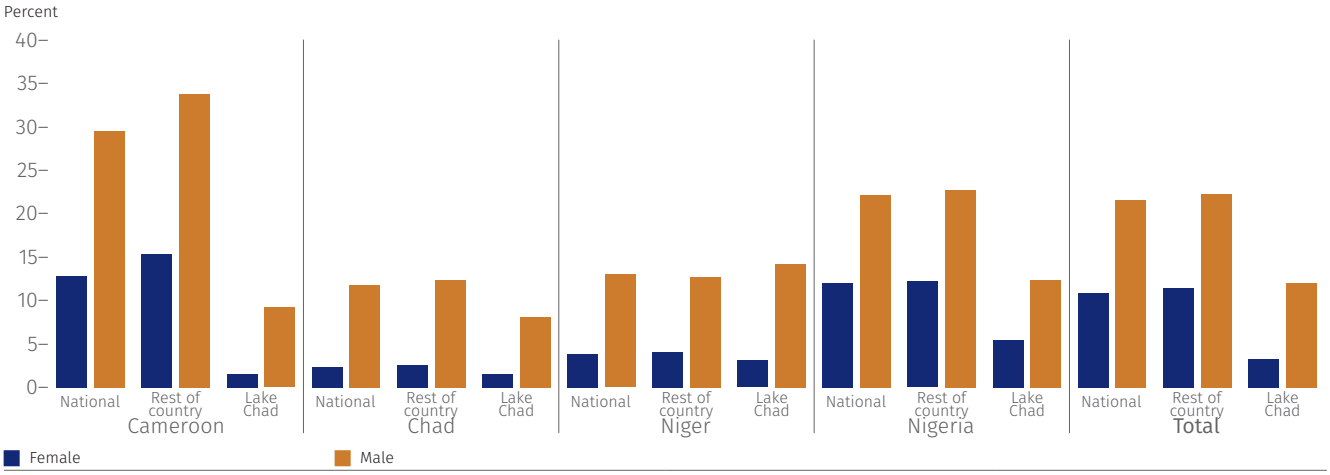
Figure 1.6: Employment type across the Lake Chad region



Source: World Bank calculations based on the latest household surveys available in Cameroon (2014), Chad (2018), Niger (2018), and Nigeria (2018).
Note: Nigeria's latest household survey does not differentiate between paid and unpaid employment. Thus, only for Nigeria unpaid employment is subsumed in self-employment. Includes only working-age individuals (ages 15–65). Rest of country = outside the Lake Chad region; Lake Chad = within the Lake Chad Basin region.

50 Nonremunerated employment includes apprenticeships and family workers. Nigeria's latest household survey does not differentiate between paid and unpaid employment and the latter is subsumed in self-employment. Because of the sampling design of the Nigeria 2018 survey, distinguishing between unpaid and wage employment is not possible for this country.

Figure 1.7: Wage employment by gender across the Lake Chad region



Source: World Bank calculations based on the latest household surveys available in Cameroon (2014), Chad (2018), Niger (2018), and Nigeria (2018).
Note: Data Include only working-age individuals (ages 15–65). Rest of country = outside the Lake Chad region; Lake Chad = within the Lake Chad Basin region. Nigeria's latest household survey does not differentiate between paid and unpaid employment. Thus, only for Nigeria, unpaid employment is subsumed in self-employment.

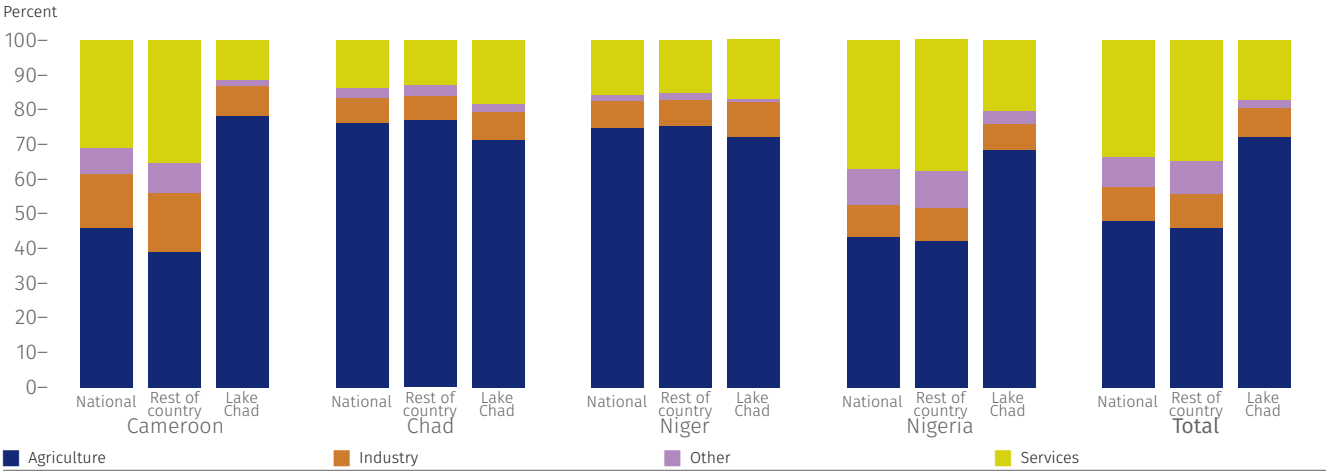
The gender gap in access to wage employment is more pronounced across young individuals ages 15–24. At the national level, 8 percent of young women engage in wage employment (4 percentage points lower than adult women) compared with 13 percent of young men (11 percentage points lower than adult men) in the four basin countries. In the Lake Chad region proper, the share of young women who have wage employment is roughly one-third that of men (3 percent versus 8 percent, respectively). This gap more than doubles among adult individuals, where 13 percent of men have wage employment, compared with 4 percent of adult women. These figures attest to low access to quality jobs across the Lake Chad region among young individuals, particularly among young women.

Agriculture—including farming, fishing, and hunting— is the predominant sector of employment in the Lake Chad region. Around 72 percent of workers are employed in agriculture across the four countries in the Lake Chad region, employing 70 percent of men and 73 percent of women.[51] In Cameroon and Nigeria, the share of people in agriculture in the lake basin is much higher compared with the rest of the respective countries (Figure 1.8). In the Cameroonian area of Lake Chad, 79 percent of workers are employed in the agricultural sector compared with half that rate (39 percent) in the rest of the country. The proportions are slightly less extreme in Nigeria, but still large, with 72 percent of workers in agriculture in the Nigerian section of the lake compared with 42 percent in the rest of the country (Figure 1.8). Chad and Niger do not exhibit major differences in subnational areas given that most of the national economy is already heavily dependent on agriculture in the two countries. The role that agriculture plays in employment and the labor market highlights the importance of opening (and keeping open) agricultural trade and agricultural markets, which closed down as a result of the crisis.

The service sector is the second largest source of employment across the Lake Chad region, but the sector's share is significantly higher in other parts of the countries. On average, 17 percent of workers are employed in the service sector in the Lake Chad region (Figure 1.8). In Cameroon and Nigeria, the employment share in the service sector in the lake region stood at 11 percent and 20 percent, respectively, compared with 35 percent and 38 percent in other parts of the two countries.

51 Cameroon has the highest labor share of agriculture, at 78 percent of workers and Nigeria the less high, at 69 percent.

Figure 1.8: Distribution of employment by sector across the Lake Chad region (4-digit)

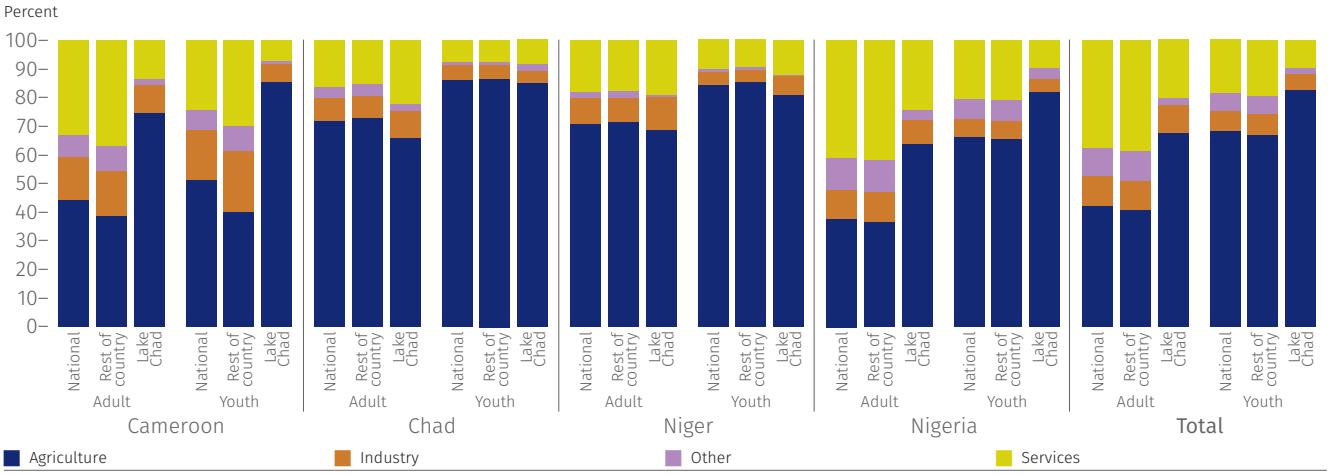


Source: World Bank calculations based on the latest household surveys available in Cameroon (2014), Chad (2018), Niger (2018), and Nigeria (2018).
Note: Data Include only working-age individuals (ages 15–65). Rest of country = outside the Lake Chad region; Lake Chad = within the Lake Chad Basin region.

Gender gaps within the service sector are also significant. In the service sector in the Lake Chad region, men are employed at a higher rate than women (20 percent and 14 percent, respectively). This pattern does not hold, however, in areas far from the lake, where a larger share of women are employed in the service sector (40 percent), compared with men (30 percent). Youth employment in the service sector in the Lake Chad region is roughly the same for men and women (10 and 9 percent, respectively). But differences exist between the region and elsewhere: youth employment in the service sector among women in the areas surrounding the lake is less than half compared with the areas outside the Lake Chad region, where it stands at 25 percent. A similar pattern is observed in adult employment among women, for whom the share of employment in services in areas far from the lake is 44 percent, compared with only 16 percent in areas near the lake. This gap is much narrower among adult men, among whom there is only a 10 percentage point difference in employment in services between the lake and non-lake areas. Commerce accounts for the largest share of service sector employment in the Lake Chad region. The share of employment in commerce is 10 percent among both men and women in the Lake Chad region. This is one-third the employment share in commerce in areas outside the region among women (nearly 31 percent), and lower than the share among men (at 15 percent). A similar pattern can be seen in youth employment among women in commerce, which is less than half compared with areas outside the Lake Chad region.

A larger proportion of young workers engage in agriculture compared with adults. Agricultural jobs are concentrated among young workers (ages 14–25), with 83 percent employed in the agricultural sector in the Lake Chad region, compared with 68 percent among adults (Figure 1.9). The share of employment in agriculture among youth is much lower outside the Lake Chad region. Among young individuals, the share of agricultural employment decreases to 67 percent in the rest of the country. A similar pattern is observed among adults (down to 41 percent). The country with the highest differential is Cameroon, where the share of youth employment in agriculture in areas near Lake Chad is 86 percent, compared with 40 percent in the rest of the country. A similar pattern is also observed among older workers. In contrast, in Niger, there is little difference in the share of agricultural employment between areas near Lake Chad and the rest of the country (Figure 1.9). Considering the distribution of gender as well as age in areas near the lake, it emerges that 84 percent of young men are employed in agriculture, compared with 66 percent of adult men. The gap between young people and adults is more acute among women, where 82 percent of young women are employed in agriculture, compared

Figure 1.9: Distribution of employment by sector and age (youth versus adults) (4-digit)



Source: World Bank calculations based on the latest household surveys available in Cameroon (2014), Chad (2018), Niger (2018), and Nigeria (2018).
Note: Data Include only working-age individuals (ages 15–65). Youth includes individuals ages 15–24. Adult includes individuals ages 15–65. Rest of country = outside the Lake Chad region; Lake Chad = within the Lake Chad Basin region.

with 70 percent of adult women in the lake areas. In areas away from the lake, the gap widens; employment in agriculture among young women stands at 61 percent, compared with 38 percent among adult women.

1.4 Territorial Development within the Lake Chad Region

1.4.1 Density

Economic stagnation in the region is linked to low levels of density and urbanization: urban agglomerations in the region have grown more quickly, widening spatial gaps, while the shrinking of the lake between the 1960s and mid-1990s pushed people to migrate from rural to urban areas.

Enduring poverty and slow economic growth in the Lake Chad region have been linked to economic geography. A combination of *low* economic density and great distance and wide division appear to be derailing the region from a sustainable growth track. Density refers to the economic mass or output per unit of land area. It can be measured as the value added or GDP generated per square kilometer of land.[52] The concentration of economic activity rises with development. Density tends to characterize urban settlements, though it can be low even if population density is high, such as in low-income urban enclaves.

1.4.1.1 Economic Density

The Lake Chad region is characterized by low economic density and lack of agglomeration economies. While the Lake Chad region accounts for 17 percent of the area of the four neighboring countries, its economy makes up only 5 percent of the relevant GDP (Map 1.9).[53] Most economic activities in the region are spatially concentrated among a few large cities. Two metropolitan cities have a population of over one million—N'Djamena and Maiduguri. A few other secondary cities contribute to the economy of the region, including Damaturu (Nigeria), Jimeta (Nigeria), Maroua (Cameroon), Mubi (Nigeria), and Zinder (Niger). In Cameroon, most economic activities in the Lake Chad region are concentrated in the southern part of the Far North Region, particularly around the city of Maroua.[54] In Niger and Chad, the volume of economic activity in the regions around Lake Chad is small and tends to cluster around areas near the borders with Cameroon and Nigeria.

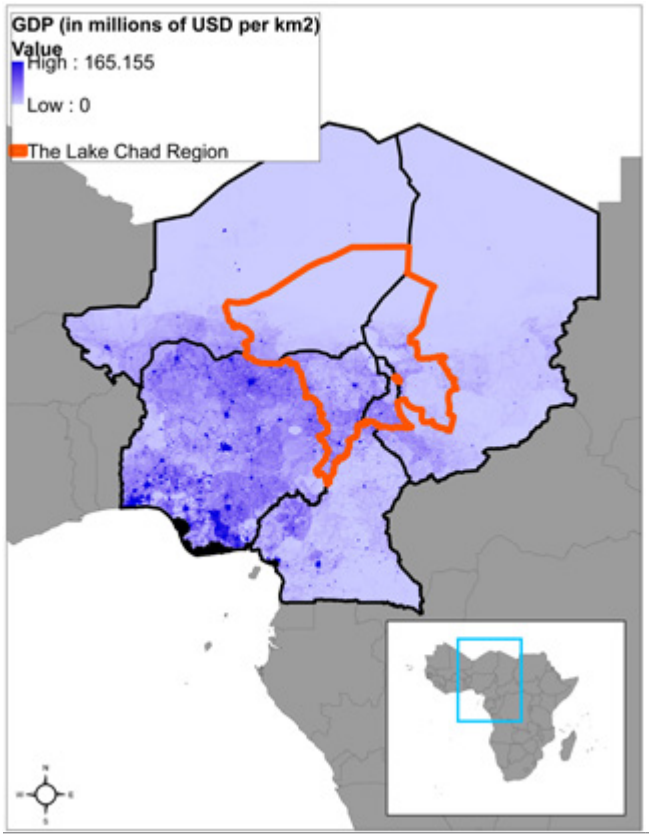
1.4.1.2 Urbanization[55]

The long-term shrinking of the lake observed until the mid-1990s had a negative impact on local population growth. The analysis presented here takes advantage of a novel dataset based on digitalized population censuses.[56] The dataset tracks population patterns at a granular level between the 1950s and the 2010s, facilitating an assessment of local population growth. The findings of the analysis show that areas close to the lake experienced relatively slower total population growth after the lake began to shrink around the early 1960s up to the mid-1990s.[57] In Niger, for instance, a one standard deviation in proximity to the lake is associated with a 0.3 and 0.5 standard deviation decrease in log population by 1969 and 1988, respectively, relative to the population level as first recorded in 1962—a few years before the lake began

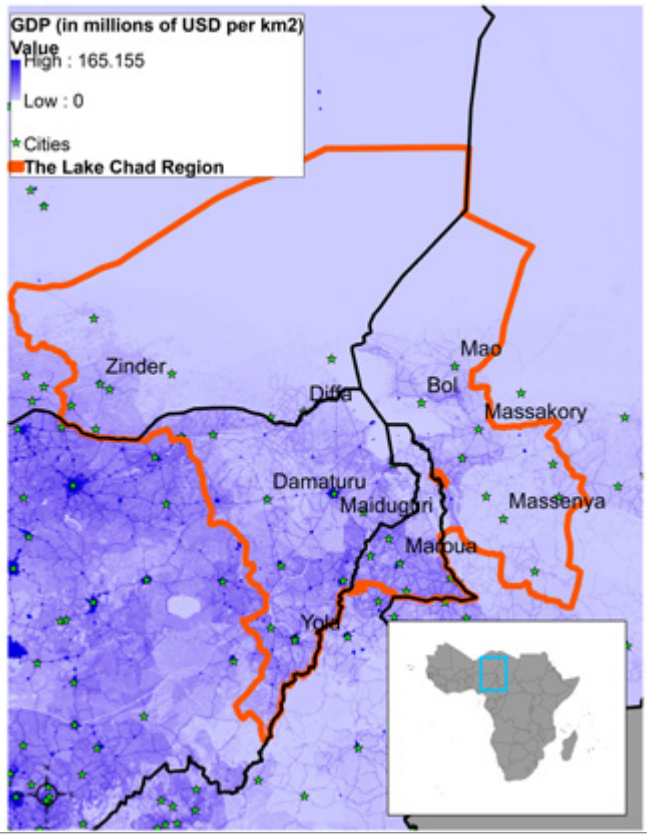
52 World Bank (2009).
53 Calculated based on Ghosh et al. (2010).
54 See UNHCR and World Bank (2016).
55 Due to data limitations, this report does not assess forced displacement in the Lake Chad region, which is certainly an important topic.
56 The results presented in this section are taken from Jedwab, Haslop, et al. 2021, technical paper for this report.
57 The observed shrinkage of the lake between 1960s and mid 1990s had to do with reduced rainfall in the Central African Republic, not local economic conditions, thus assuaging reverse causality concerns. The shrinkage of Lake Chad during those years thus offers a natural experiment to examine how long-term lake drying can affect both rural and urban communities.

Map 1.9: Economic activity in the Lake Chad region, 2010

a. Estimated subnational real GDP (2006) in Cameroon, Chad, Niger, and Nigeria

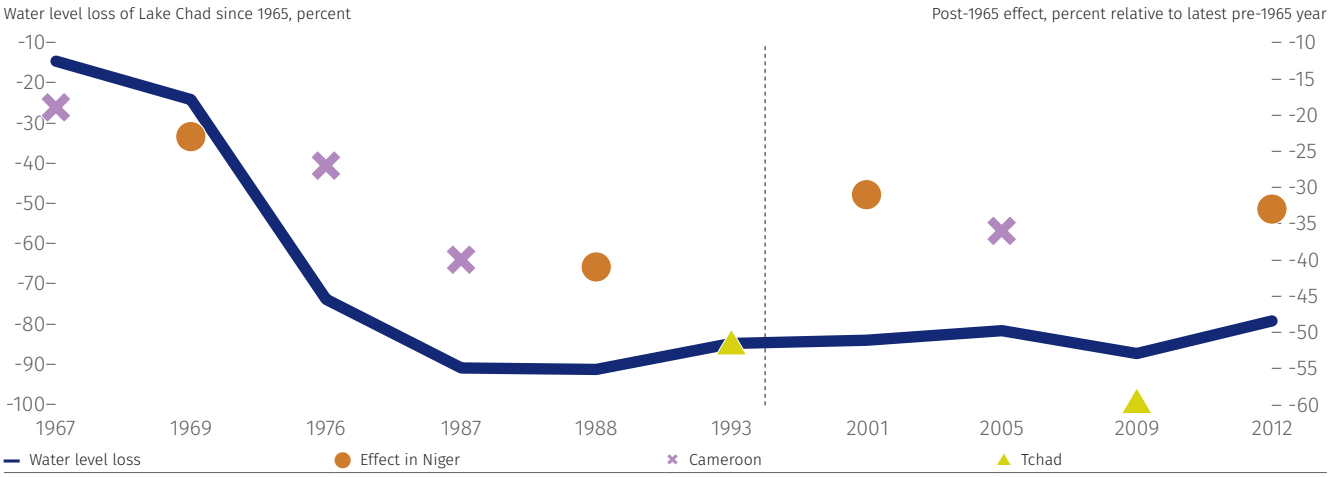


b. Estimated subnational real GDP (2006) in the Lake Chad region



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report. Calculations are based on data of Ghosh et al. 2010. GDP estimates are based on nighttime lights satellite imagery and LandScan population grids.

Figure 1.10: Total population effect of proximity to Lake Chad, 1940s–2010s



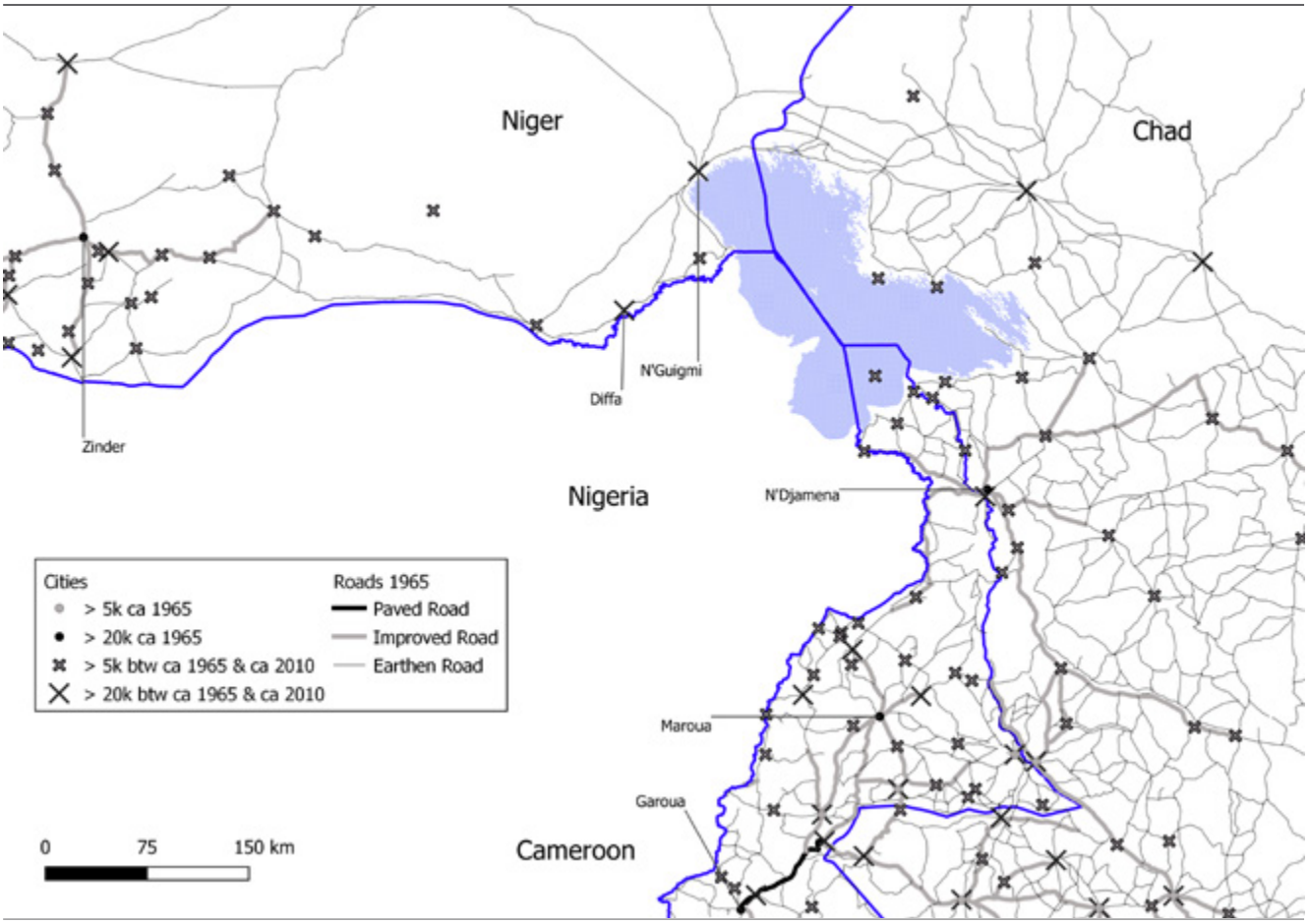
Source: Jedwab, Haslop, et al. 2021, technical paper for this report.

to shrink (Figure 1.10). Negative population effects are even larger in Cameroon, where a one standard deviation in proximity to the lake is associated with a 0.7 and 1.0 standard deviation decrease in log population in 1976 and 1987, respectively, relative to the population level in 1963. In Chad, a one standard deviation in proximity to the lake is associated with a 0.9 standard deviation in log population in 1993. Since the mid-1990s, the water level in Lake Chad has been recovering.

There are few secondary towns or cities with more than 20,000 inhabitants in the region, which could otherwise serve as a catalyst for generating agglomeration economies to foster economic growth. In Niger, between 1965 and 2012, the number of small towns (at least 5,000 inhabitants) increased from 14 to 161, while the number of (relatively) larger towns (at least 20,000 inhabitants) rose from 4 to 26. In Cameroon, the number of small and large towns increased from 51 to 173 and from 10 to 54 between 1965 and 2005, while, in Chad, the corresponding numbers rose from 11 to 94 and from 4 to 23 between 1964 and 2009 (Map 1.10).

The shrinking of the lake observed between the 1960s and the mid-1990s led to migration from rural areas to cities near the lake. The analysis finds signs of refugee urbanization in areas near the lake because of the lake's shrinkage during these years.[58] As access to the rich water

Map 1.10: Trends in city population around Lake Chad, circa 1965–2010



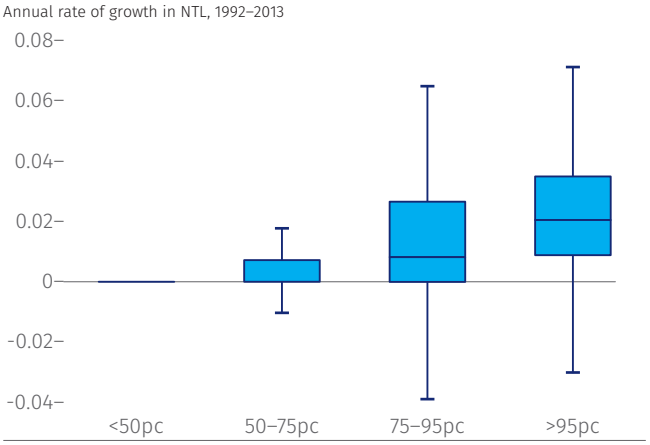
Source: Jedwab, Haslop, et al. 2021, technical paper for this report.
Note: The map shows the location of 5,000+ and 20,000+ urban settlements circa 1965, when the lake started shrinking, and circa 2010, at the end of the period of study. It also indicates regionally important (20,000+) cities in the 1960s, such as Diffa, N'Guigmi and Zinder in Niger, N'Djamena in Chad, and Maroua and Garoua in Cameroon. It also shows paved roads, improved roads, and earthen roads, all circa 1965.

58 See Jedwab, Haslop, et al. 2021, technical paper for this report.

resources and economic opportunities provided by Lake Chad became increasingly limited, people in the region may have migrated to cities in search of better economic opportunities. This phenomenon was particularly visible in Niger, where the shrinkage of Lake Chad between the 1960s and mid-1990s had a clear positive impact on the expansion of larger cities around the lake. Despite the existence of many rural settlements and small towns close to the lake, there were no small cities in eastern Niger and no large cities close to the lake in 1962. But two large cities—Diffa and N'Guigmi—rose quickly in the area. Diffa had fewer than 1,000 inhabitants in 1962; yet, by 2012, it had become Niger's 11th largest city. N'Guigmi was historically located on the shore of the lake, a center for fishing communities. Its dramatic growth from 3,000 people in 1962 to more than 25,000 today must have been driven by the locality functioning as a refugee settlement for individuals who had lost their rural livelihoods. As these two larger cities emerged, the need for smaller cities might have been reduced; hence, the negative effect observed among these smaller locations. A similar pattern of refugee urbanization was also observed in Cameroon during the years of the shrinkage of the lake, although the positive effects on city populations were much weaker in Cameroon compared with Niger. In Chad, no such effect was observed.

More densely populated urban agglomerations continue to grow faster than less densely populated areas, thereby widening spatial gaps in density. Controlling for the level of economic activity (as proxied by nighttime lights in 1992), the initial level of population density is positively correlated with the annual rate of economic growth measured by the intensity of nighttime lights (Figure 1.11). More substantively, a 1 percentage point increase in the initial level of population density is associated with a 0.2 percent increase in the annual rate of growth in nighttime lights.[59] The findings are consistent with other studies showing that the locations of urban agglomerations remain persistent over time, even after controlling for other factors that led to their establishment in the first place.[60] Urban agglomerations continue to grow more quickly than more sparsely populated areas, and this has important implications for widening spatial gaps between core cities and the rest of the countries.

Figure 1.11: Population density is positively correlated with regional growth, 1990



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: Excludes outside values. The bottom of the rectangular box represents the lower quartile (25th percentile), and the top is the upper quartile (75th percentile). The horizontal line indicates the 50th percentile, which is provided for different initial levels of population density in 1990, ranging from the bottom 50 percentile (< 50 pc) to above the top 95 percentile (> 95 pc). The analysis is performed based on the sample of 5,212 grid cells (at a spatial resolution of 0.1 degrees) defined over the Lake Chad Basin countries that were lit (with a positive digital number in nighttime light luminosity) at some point between 1992 and 2013.

1.4.1.3 Regional Convergence (Conditional Convergence)

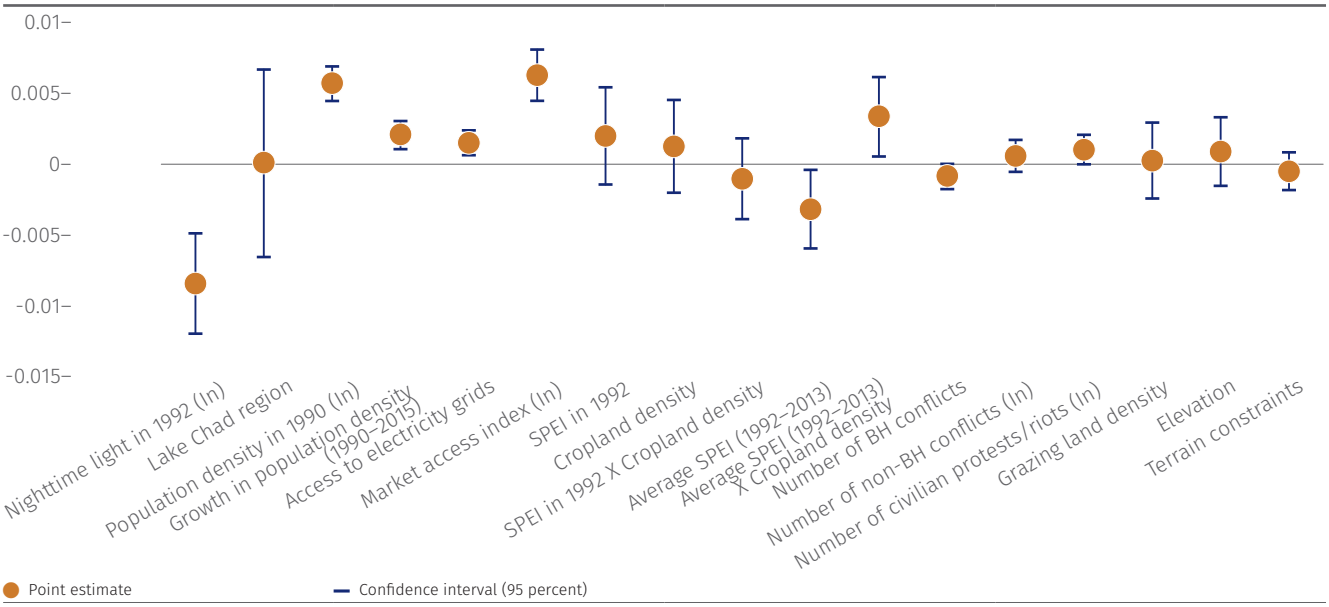
The Lake Chad region as a whole does not show a clear sign of convergence with the rest of the countries in terms of local economic growth, thereby implying the perpetual nature of laggardness in the region. According to a multivariate regression analysis exploring the main drivers of local growth as measured by the annual rate of change in nighttime lights, the pace of local economic growth in the Lake Chad region is not statistically different from that of the other parts of the countries after one controls for other potential confounders

59 This relationship holds whether the analysis is performed for all the Lake Chad Basin countries or restricted to the Lake Chad region only.
60 Henderson et al.(2018); Jedwab et al.(2017).

(Figure 1.12).[61] This implies that, conditional on various socioeconomic and geographic factors, the Lake Chad region is no different from the rest of the countries in the pace of growth. However, what this analysis also shows is that the laggardness of the region is persistent over time, with little economic dynamism in the region that might allow it to catch up with the rest of the countries. There are also some important differences across the Lake Chad Basin countries. In particular, as seen in Map 1.6, panel d, the spatial gap between areas near Lake Chad and the rest of the country is clearly deepening in Nigeria, with areas near Lake Chad experiencing a slower rate of growth in nighttime lights.

Two factors stand out as the key determinants of the trajectory of local economic growth: the initial level of nighttime light luminosity and population. These two variables explain roughly 20 percent of the variation in the annual rate of growth in nighttime lights. This is perhaps not surprising given that nighttime lights are a function of both population density and economic activity.[62] One way to interpret these results is that urban areas that initially had low levels of development (or luminosity) grew more quickly than other areas that exhibited high levels of development, thus narrowing the gaps between lagging and more advanced cities if one controls for population density and other socioeconomic factors.[63] This finding echoes a well-established body of literature on regional convergence whereby poor economies grow more quickly than rich economies.[64] Another important factor that drives regional growth is access to markets (see the following section). Meanwhile, exogenous geographical factors, such as land use (cropland or grazing land), elevation, and terrain constraints have no significant impact on regional economic growth.

Figure 1.12: Main correlates with local economic growth: Regression analysis



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: The results are based on the beta-convergence regression wherein the dependent variable is the annual rate of growth in nighttime light luminosity between 1992 and 2013 and regressed on a number of socioeconomic, demographic, and geographical variables. The analysis is restricted to areas that are lit at some point between 1992 and 2013 and thus exclude largely rural or unpopulated areas. For ease of comparison, all the variables are standardized so that the result shows the effects of a standard deviation in each variable on the annual rate of growth in nighttime lights.

61 Note that this analysis is restricted to areas that are lit at some point between 1992 and 2013 (indicated by a positive value in digital number of luminosity).

62 Henderson et al.(2018).

63 World Bank (2009).

64 See Barro and Sala-I-Martin's and Bairro et al.'s (1995) seminal work on this topic. Our work is not the first to use nighttime light as an instrument to empirically test convergence. Gennaioli et al. (2015) and Chandra and Kabiraj (2020), for instance, also use nighttime light to explore how lagging regions may catch up to more advanced regions and find strong evidence of convergence.

1.4.2 Distance (Lack of Connectivity)

Closing connectivity gaps in the Lake Chad region can lead to higher productivity and higher-quality jobs, particularly in rural areas, where people are twice as likely to be disconnected from main roads, and thus from access to markets and economic opportunities.

The Lake Chad region suffers not only from a lack of density, but also from long distance or lack of connectivity to the rest of the countries or to the neighboring countries. *Distance* refers to the ease or difficulty for goods, services, labor, capital, information and ideas to traverse space. It measures how easily capital flows, labor moves, goods are transported, and services are delivered between two locations. In this sense, distance is an economic concept not just a physical one, related to connectivity and access. An area is more likely to be lagging the farther away it is from leading areas since greater distance-to density implies a lack of integration into the economy. It also implies poorer access to the "thick" markets of capital, labor, goods, services and ideas, and the spillovers of knowledge and information they provide. As highlighted in this section, the Lake Chad region exemplifies an area that lacks access to major markets due not only to its landlocked geography but also due to poor connective infrastructure and intensifying conflicts that make the flow of people and goods across the region extremely costly.

1.4.2.1 Market Accessibility

Rural people in the Lake Chad region are twice as likely to be disconnected from all-season roads (motorable year-round), compared with areas in the rest of the countries. The score of the rural access index—that is, the share of rural population living within 2 kilometers of an all-season road—is low for the region (Map 1.11, panel a).[65] Nearly two-thirds of about 60 percent of the rural population in the Lake Chad region live farther than 2 km away from an all-season road (proxied by *OpenStreetMap*), that is, about twice the share in the non-lake parts of the basin countries (about 30 percent).

Conflict and border closers have further distanced rural populations from the market. For example, take-home profits for small producers and sharecroppers reduced by about 80 percent before and after the Boko Haram crisis and its associated border closures.[66] Sales volumes have decreased while the cost of agricultural inputs has risen (as cheaper Nigerian imports are not available and small farmers are unable to cross the river to purchase small amounts). As a result, the crisis has decreased the potential of the dried red pepper market to act as a source of income for producers, and as a source of employment, where producers report having to lay off daily laborers and having less ability to offer sharecropping opportunities to the poor.

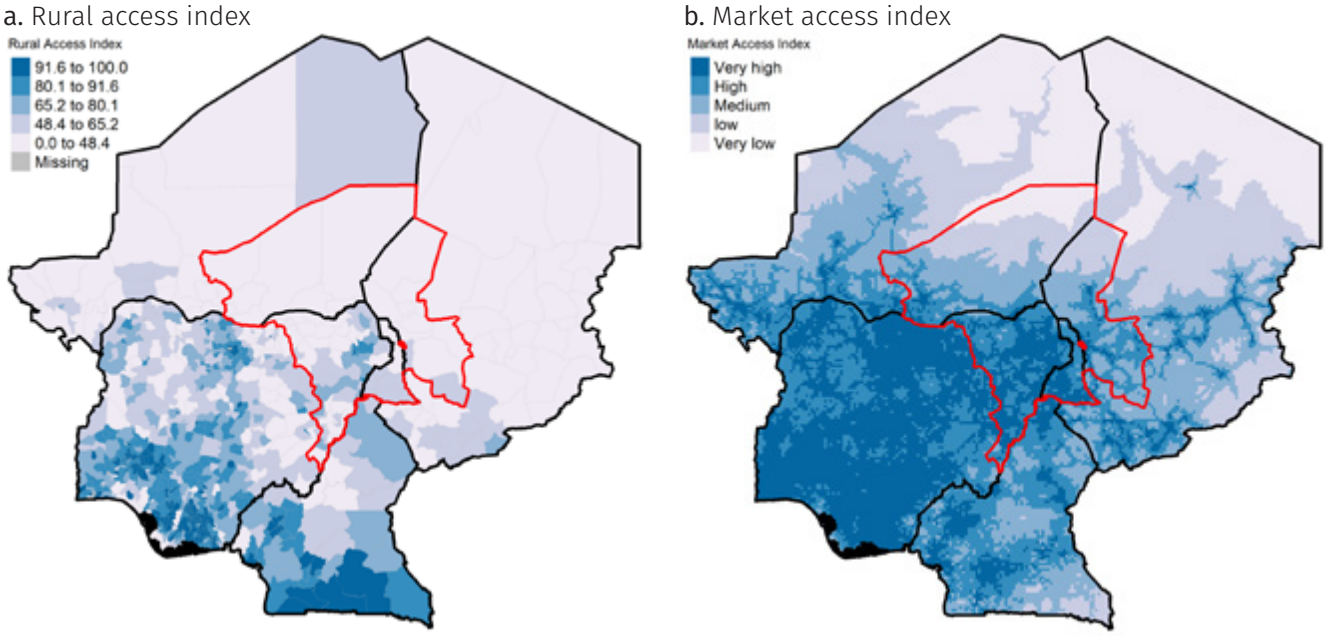
The Lake Chad region and its vicinities host several key cities (Maiduguri in Nigeria, Maroua and Kousséri in Cameroon, N'Djamena in Chad, and Diffa in Niger) that can serve as trade hubs for driving the regional economy. The Market Access Index–a measure of the size of population that can be reached within a certain travel time[67]–is relatively high in the Lake Chad region compared with some other parts of the countries (Map 1.11, Panel B). This indicates that, with proper connective infrastructure, people in the Lake Chad region could benefit from economic opportunities that large markets—both within and around the region—can offer. Road transportation connects some key local agricultural markets in and around the Lake Chad

65 An "all-season road" is defined as a road that is motorable all year round by the prevailing means of rural transport. Trunk, primary, secondary, and tertiary roads in *OpenStreetMap* are used as a proxy for all-season roads following the methodology by Azavea: https://rai.azavea.com/.

66 Sissons, Corrie and Clotilde Lappartient. 2016. "A Modified Emergency Market Mapping Analysis (EMMA) and Protection Analysis: Smoked Fish and Dried Red Pepper Income Market Systems - Diffa Region, Eastern Niger." Oxfam GB, Oxfam House, John Smith Drive, Cowley, Oxford, OX4 2JY, UK.

67 Estimated travel time to the closest city with a population of 500,000 or greater.

Map 1.11: Market and rural access in and around the Lake Chad region



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: Panel a shows the rural access index or the share of the rural population who live within 2 kilometers of all-season roads as proxied by OpenStreetMap. See appendix B for details on the construction of the index. Panel b shows areas that score very high (top 20 percentile), high (20–40 percentiles), medium (40–60 percentiles), low (60–80 percentile), or very low (bottom 20 percentile) in the market access index. See appendix B for details on how the index is calculated.

region, including (a) Bol and N'Djamena in Chad, (b) Kousséri in Cameroon, (c) N'Guigmi and Diffa in Niger, and (d) Bosso, Niger, along with Marte and Monguno via Madiguri in Nigeria. Maiduguri is an important connection for the trade corridors between Nigeria and Cameroon.[68] Yet, due to security concerns, many roads remain closed and border restrictions also further limit the movement of people and goods across the region—a topic that is discussed more in details in Section 1.4.3.

1.4.2.2 Poor Road Infrastructure

Poor road infrastructure—compounded by insecurity—undermines both intra- and inter-regional connectivity. Connectivity across borders (or between cities within national boundaries) is poor due to insufficient road infrastructure and a volatile security situation, which make trade and transportation of goods costly. Access to the Lake Chad region from the exterior is at best poor, aside from a paved road in Chad (N'Djamena to Karal), which is barely functional. The conditions of travel within and between the areas surrounding the lake are also difficult because of invasive vegetation on the body of water, which obstructs navigable channels, and due to the lack of maintenance of rural roads. The northern basin and the north-east archipelago are landlocked, which slows down the diversification and intensification of the farming economy. Additionally, insecurity is reported as one of the main causes of concern for transporters, alongside the quality of road infrastructure, and excessive checkpoints and payments on routes.[69] Better connectivity and mobility within the Lake Chad region—and also between the region and other areas of the countries—have the potential to improve the living conditions of the population, by improving access to basic services, jobs, and markets.

68 See Appendix 1.A for a map of local markets in the region.
69 WFP (2016a, 2016b).

1.4.2.3 Digital Connectivity

In addition to physical disconnectivity due to a lack of sound road infrastructure, the Lake Chad region also suffers from digital disconnectivity, further isolating the region not only from the rest of the Lake Chad Basin countries and also from the rest of the world. Access to the Internet is also limited in the Lake Chad Basin countries. While digital infrastructure in Sub-Saharan Africa as a whole is lagging behind compared with the rest of the world,[70] the Lake Chad countries have a particularly low level of internet penetration. Approximately 12 percent of the population in the Lake Chad countries reported using the internet, compared with 19 percent across Sub-Saharan Africa, on average.[71] There is heterogeneity within the region. Chad lies among the countries with the lowest internet penetration rates in the world, at 7 percent of the population, compared with Cameroon, which at 23.2 percent ranks above the regional average.

Mobile internet in the Lake Chad Basin countries has undergone a rapid expansion, although its pace still lags regional leaders like South Africa. Unique mobile internet subscribers across the Lake Chad Basin countries increased almost twofold as a share of the population between 2014 and 2020.[72] In 2020, this figure stood at 31 percent of the population, above the regional Sub-Sahara African average of 28 percent. However, the share of unique mobile internet subscribers in Lake Chad countries remains substantially below regional leaders, such as South Africa (52 percent). Chad registered a unique mobile internet subscription rate of 17 percent of the population in 2020, compared with 34 percent in Nigeria and 34 percent in Cameroon. On the other hand, Niger has the lowest mobile internet penetration rate across the Lake Chad region, and among the lowest in Sub-Saharan Africa. It is important to identify the main constraints to adopt internet services faced by individuals to fully harness the potential benefits of digital technologies in the region.

Digital infrastructure—mobile broadband internet in particular—is limited in the Lake Chad region.[73] A large swath of areas in the Lake Chad region have little connectivity to fiber optics transmission nodes or 3G technology except for the Far North Region of Cameroon where there appears to be more comprehensive coverage.[74] Access to the internet (either through fixed broadband or mobile broadband) can serve as a catalyst for poverty alleviation,[75] improved labor outcomes[76] and the functioning of rural markets,[77] specifically regarding price information, access to inputs and consumers[78] and access to capital markets.[79] Thus, together with a lack of physical connectivity, poor digital connectivity presents

70 World Bank (2019a).

71 Data of 2017, WDI (World Development Indicators) (database) (accessed on 04/07/2021), World Bank, Washington, DC, https://datatopics.worldbank.org/world-development-indicators/. Internet users are individuals who have used the internet (from any location) in the last 3 months. The internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.

72 Given that consumers may use multiple SIM cards to take advantage of discounts or to avoid high charges for off-network calls, market penetration in terms of unique subscribers may provide a better picture of the degree of access to mobile services. GSMA defines mobile internet as the use of internet services by unique users on mobile devices at the end of a given period. Mobile internet services are defined as any activity that uses mobile data (that is, excluding SMS, multimedia messaging services, and cellular voice calls). See GSMA Intelligence (database), Global System for Mobile Communications (GSM Association), London, https://www.gsmaintelligence.com/. Accessed on April 7 2020.

73 Hjort and Poulsen (2019).

74 The nodes correspond to add or drop points (entrance or exit) in the long-haul fiber networks. Long-haul fiber networks are like motorways that have junctions (on and off ramps, that is, add and drop points) that feed smaller class roads (access fiber, wireline, and wireless networks). In the motorway scenario, even if a household is located close to the motorway, it may be a long drive to the nearest junction. The same applies to fiber-optic networks, in which the speed of fixed broadband Internet is determined by proximity to the transmission nodes rather than the network lines connecting the nodes. While second-generation (2G) technologies enable voice, SMS, and limited Internet access, third-generation (3G) technologies enable more rapid Internet browsing and data downloading. The 2G/3G coverage data should be treated with caution, however; see the note to map 1.12.

75 See Bahia et al. (2019) and Masaki et al. (2020).

76 See Hjort and Poulsen (2019); Paunov and Rollo (2014); Fernandes et al. (2019); Chun and Tang (2018); Viollaz and Winkler (2020).

77 See Kaila and Tarp (2019); Goyal (2010); Ritter and Guerrero (2014); Salas-Garcia and Fan (2015).

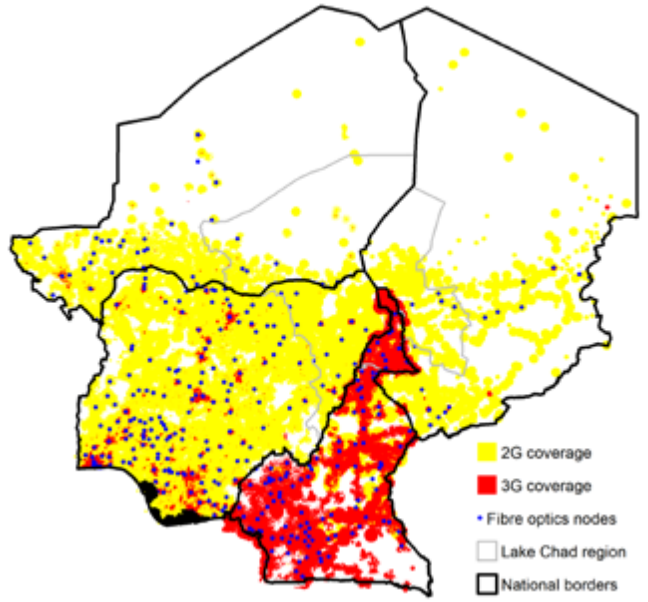
78 See Aker and Mbiti (2010); Aker (2011); Debo and Van Ryzin (2013).

79 See Hasbi and Dubus (2019); Alibhai et al. (2018).

an additional hurdle that prevents the region from tapping its full economic potential.

Not only is access to digital infrastructure limited, ownership of digital devices like cellular phones is also particularly low in the Lake Chad region. Cell phone ownership as a share of population in the areas near the lake in Niger stood at 13 percent compared with 20 percent for the rest of the country. A similar pattern can be seen in Nigeria, where cell phone ownership is 5 percentage points lower in the regions near the lake. Chad is the only exception, where ownership is higher in areas near the lake compared with the rest of the country (20 percent versus 16 percent, respectively).

Map 1.12: Digital connectivity in and around the Lake Chad region (2018–2019)

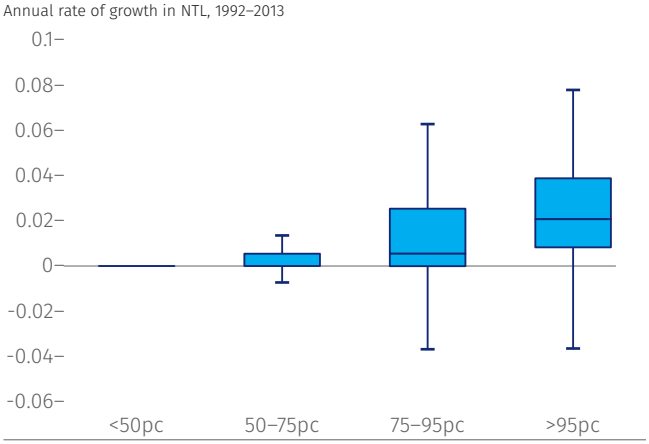


Sources: Africa Bandwidth Maps (dashboard), Hamilton Research, Bath, UK, http://www.africabandwidthmaps.com/; Mobile Coverage Maps (dashboard), Collins Bartholomew, HarperCollins Publishers, Glasgow, https://www.collinsbartholomew.com/mobile-coverage-maps/.
Note: Mobile coverage corresponds to 2018. Fiber optics correspond to 2019. The 2G/3G coverage data should be treated with caution, however, because the Collins Bartholomew coverage maps do not necessarily include all network providers in each country. Thus, this coverage map should be treated as a lower bound of 2G/3G availability.

1.4.2.4 Reducing Distance to Markets Matters for Local Economic Development

Market accessibility is among the key drivers for regional integration and economic growth. Areas that are better connected to large markets experienced a faster rate of growth than other areas (Figure 1.13).[80] Controlling for the initial level of nighttime lights and population size as well as other socioeconomic and geographic factors (as shown in Figure 1.12), market access is indeed one of the main determinants of local growth (approximated by the intensity of night lights) in the four Lake Chad countries as well as within the Lake Chad region itself (the areas surrounding the lake).

Figure 1.13: Market accessibility index and regional growth



Source: Masaki and Rodríguez-Castelán 2021, technical paper for this report.
Note: Excludes outside values. The results are based on the beta-convergence regression where the dependent variable is the annual rate of growth in nighttime light luminosity between 1992 and 2013 and regressed on a number of socioeconomic, demographic, and geographical variables. The analysis is performed based on the sample of 5,212 grid cells (at a spatial resolution of 0.1 degrees) defined over the Lake Chad Basin countries that were lit (with a positive digital number in nighttime light luminosity) at some point between 1992 and 2013.

Connectivity to regional hubs like N'Djamena and Maiduguri appears to be particularly important for growth in agriculture and livestock trade. For instance, fish routes were still supplying several tons of produce to the regional hubs of N'Djamena and Maiduguri with an annual estimate of 50,000 to 100,000 tons of fish

80 These results are drawn from Masaki and Rodríguez-Castelán (2021), technical paper for this report.

per year between 2010 and 2014.[81] As noted above, the livestock trade is vital for the region and crossborder trade has long played a role in trade in livestock markets in Africa.[82] Traditionally, livestock trade routes from Chad and Niger pass through Maiduguri on the way to regional markets.[83] Sixteen out of 97 large livestock markets in the four countries are located nearby Lake Chad, while more than half of the livestock markets are within 100km of the border.[84]

Improved access to markets serves to expand agricultural activities. An analysis of access to markets and land cultivation using over three decades of remotely sensed and geospatial panel data shows that an increase in market access is associated with an increase in cultivated land.[85] Given the modest gain in length of paved road, the growth in population, which is a proxy for the size of the market, is the main driver for the increase in market access. A 1 percent increase in market access is associated with a 3.9 percent increase in cropland area. Given the approximate total of cropland in the four countries is nearly 600,000 km^2, this result implies a growth of around 23,400 km^2 given a 1 percent increase in market access over 9 years.[86]

The positive impact of market access on agricultural activities is constrained by conflict and insecurity. As discussed above, market access is associated with an increase in cropland area. This result, however, does not incorporate short-term shocks or uncertainty in traveling to markets, especially related to conflict.[87] Indeed, the same analysis shows that areas that are closer to conflict events experience slower cropland expansion over the entire region.[88] These findings imply that investments in enhancing connective infrastructure to improve market access for the Lake Chad region does not guarantee gains in agricultural expansion unless such investments are made in tendon with complementary policies to secure peace and security in the region or at least mitigate the negative impact of conflict.

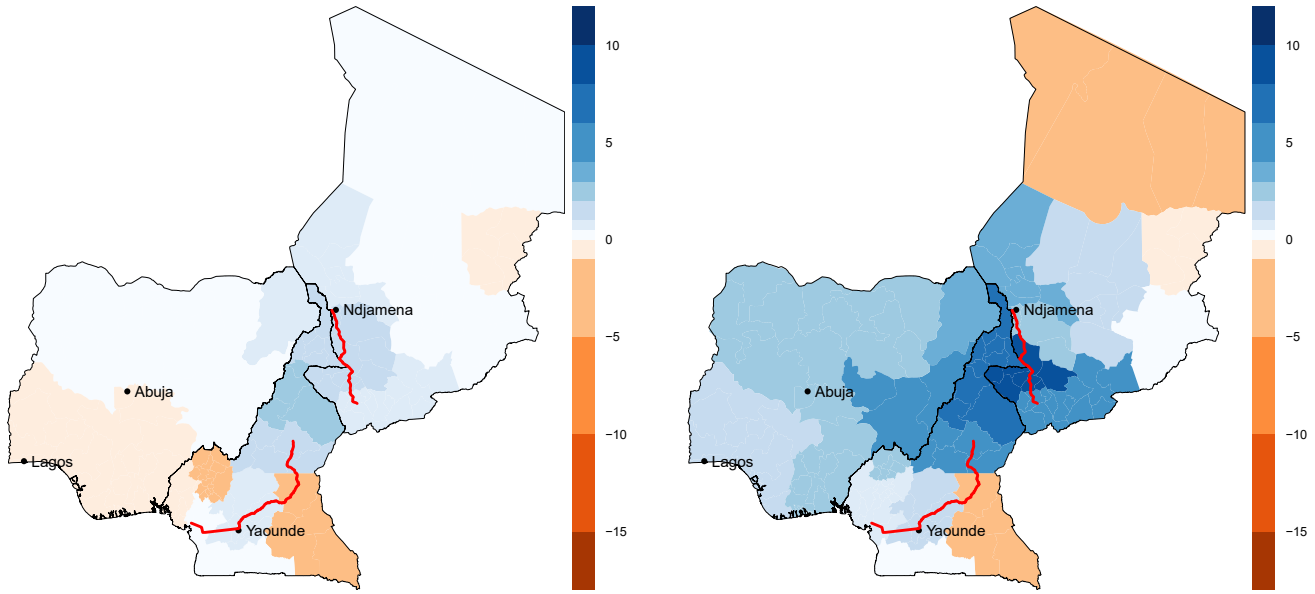
Better access to connective infrastructure in the Lake Chad region is also associated with a shift away from agricultural jobs. Using data on the expansion of infrastructure and the sectoral composition of employment at the subnational level, the analysis[89] shows that access to paved roads is linked with diversification away from agriculture in the Lake Chad region. More substantively, having access to paved roads is associated with a 6 percentage point reduction in the employment share of agriculture, and a 4 percentage point increase in the employment share of manufacturing and a 2 percentage point increase in the employment share of services. These effects are even larger in the districts neighboring Lake Chad, where having access to a paved road at the district level is associated with a 13 percentage point reduction in the employment share of agriculture, a 8 percentage point increase in the employment share of manufacturing, and a 5 percentage point increase in the employment share of services. In particular, road connectivity appears to have particularly significant impact in Cameroon, where access to paved roads is associated with a reduction in agricultural employment by 12 percentage points and roughly a 6 percentage point increase in both manufacturing and service sector employment, respectively.

81 Lemoalle and Magrin (2014).
82 de Haan et al. (1999).
83 WFP (2016a, 2016b).
84 Blankespoor (2021), technical paper for this report.
85 Specifically, the panel includes the following years: 1983, 1992, 2001, 2010 and 2019.
86 The harmonized night light series includes both the Defense Meteorological Satellite Program–Operational Line-Scan System and Visible Infrared Imaging Radiometer Suite satellites.
87 Travel time assumes the fastest route and does not include any measures of delays or roadblocks. Conversely, Van Der Weide et al. (2018) incorporate road closure obstacles in the travel time analysis to quantify the impact of market access on local GDP in the West Bank.
88 Blankespoor (2021), technical paper for this report.
89 The results presented in this section are taken from Lebrand (2021), technical paper for this report.

While structural transformation may directly contribute to poverty reduction in the long run, its impact may be more nuanced in the short run. As noted above in this report, despite having a relatively high share of non-agricultural employment, parts of the Lake Chad region of Nigeria and Cameroon still have relatively high poverty rates. A transition away from agriculture per se does not necessarily guarantee immediate poverty reduction and complementary policies and investments are also needed to increase productivity for farmers—which still account for a disproportionate number of the poor in the region.

Overall, the welfare effects of the new transport corridors are positive but modest unless combined with complementary policies to reduce border frictions. Map 1.13 graphically shows the estimated welfare gains from two pipeline infrastructure investments financed by the World Bank: i) an alternative road transport corridor to Chad; and ii) the rehabilitation of the rail line in Cameroon.[90] The alternative road corridor links N'Djamena, the capital of Chad, with Moundou, the second city in Chad and Ngaoundéré in Cameroon.[91] The investment project of the rail line in Cameroon consists of the renovation of the main rail line between Ngaoundéré, Yaoundé and Douala. Overall, those two transport corridor projects alone would not expect to yield substantial welfare gains without any complementary policies to reduce crossborder frictions. When combined with a reduction in crossborder frictions, regional real income (i.e. the sum of real incomes for the entire population in a given region) is expected to increase—particularly in areas within the Lake Chad region where the overall welfare gain is estimated to be around a 5 percent increase in the overall real income of people living in the region.

Map 1.13: Regional welfare impacts from transport corridor investments (left) with additional border reduction (right) - percentage change in regional welfare.



Source: Lebrand 2021, technical paper for this report.
Note: The maps show the welfare impact of the two proposed infrastructure investments with and without complementary policies to reduce border-crossing time by half. The model used to estimate expected welfare effects from the proposed infrastructure investments consider the combined effect of those investments with a reduction in travel time for crossing borders. The model assumes the effect of halving border-crossing time from 30 hours to 15 hours.

90 The model does not consider investments in electricity and internet. The plan for future research is to include those infrastructure sectors in the model and link it with the empirical analysis.

91 Because of insecurity in the Far North, road transporters now opt for this alternate route (rather than the more direct route through Maroua and Kousséri) and therefore the corridor is in need of investment to sustain the increase traffic. In 2015 alone approximately 500,000 tons of goods passed through this corridor compared with 40,000 tons through the previous corridor (CPCS-EGIS, 2019).

1.4.3 Division

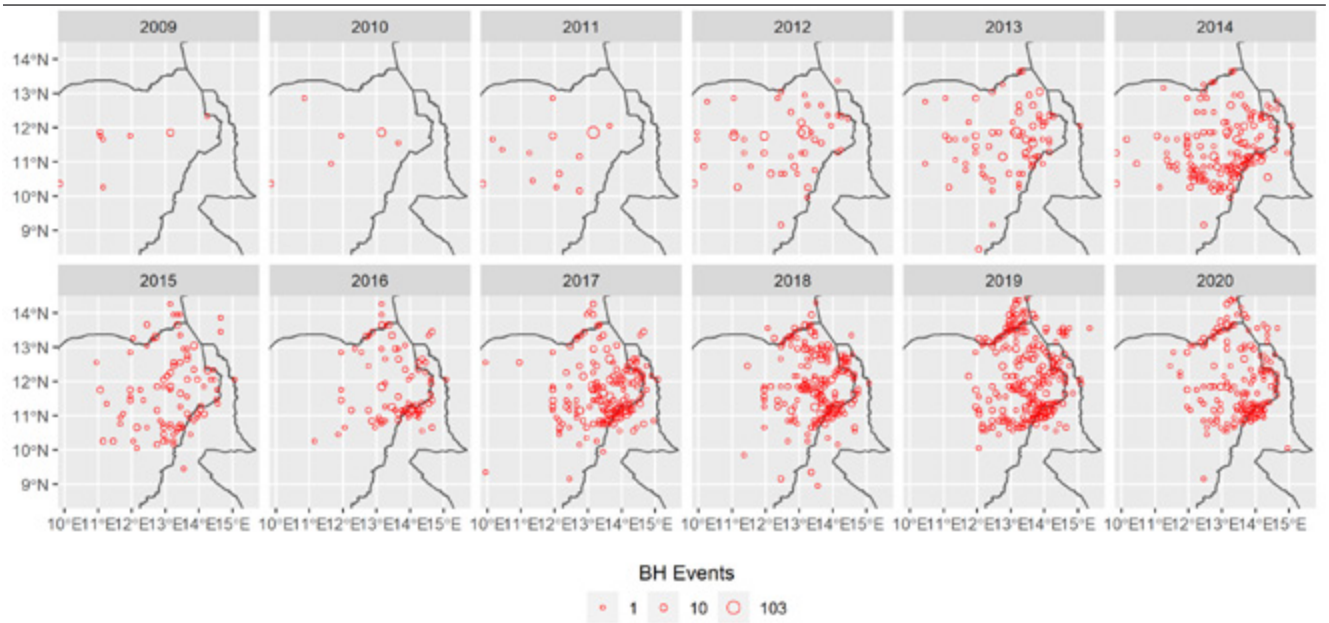
The historically strong crossborder trade around Lake Chad has been disrupted by the Boko Haram conflict, a source of division in the region. Yet, regional trade shows signs of resilience, and exploiting further trade opportunities could have a direct positive impact on household incomes and employment.

Together with density and distance, the third important geographic dimension for territorial development is division. It applies at both national and international scales. At the national scale, nations can be internally divided due to conflicts and tensions arising from linguistic, ethnic, religious, cultural, or political divisions. At the international level, divisions mainly arise from so-called thick borders, i.e., the many restrictions countries impose on other countries regarding the flow of goods, capital, people and ideas.[92] Thick borders limit trade and the flow of factors of production. Interstate conflict creates the thickest borders. While borders in the rich world have become increasingly thin, hereby facilitating trade and the movement of people and capital, borders in many developing countries remain thick, as is generally the case in the Lake Chad region. At the same time, borders in the areas around Lake Chad have historically been characterized as relatively porous—with trade and social ties permeating borders. This mobility, however, has subsided over the last decade with the hardening of borders and counterinsurgency measures as a response to the Boko Haram insurgency.

1.4.3.1 Boko Haram

The intensification of conflict in the Lake Chad region since the rise of Boko Haram in 2009 has been a large source of division driving the laggardness of the region. While the group was fist founded in 2002, the insurgency is considered to have begun in full in 2009 in Nigeria. In 2014–15, it expanded into northern Cameroon, Niger and Chad. Since then, the group has retreated into inaccessible

Map 1.14: The evolution of the number of Boko Haram violent events from 2009–2020



Sources: Blankespoor (2021). technical paper for this report. The elaboration is based on ACLED (Armed Conflict Location and Event Data Project) (dashboard), Robert S. Strauss Center for International Security and Law, Austin, TX, http://www.acleddata.com/.

92 Fratianni and Kang (2006).

areas, mainly along the borders, but has continued to carry out more frequent and sophisticated attacks.[93] Boko Haram has been aligned with the Islamic State of Iraq and the Levant since 2015.[94] It is not a unified group; in 2016 it split into two factions: the Islamic State's West Africa Province (ISWAP) and Jama'atu Ahl al-Sunnah lil-Dawa wal-Jihad (JAS).[95] At its peak—that is between 2010 and 2015—the group seized a large swath of territories in Nigeria's North East, including major cities, pushing the government of Nigeria to declare a state of emergency (an action that was later followed by other governments in the region). While most of the attacks between 2009 and 2013 were geographically concentrated in a few states in the northeastern corner of Nigeria, the terrorist group moved some of its activities to the neighboring areas of Cameroon, Chad, and Niger (Map 1.14). Vigilante groups have been created in response to the insurgency, and these are becoming increasingly violent.

1.4.3.2 Crossborder Trade Barriers

The Lake Chad Region has historically been characterized as a system of (mainly informal) regional and crossborder trade. The Lake Chad region is heavily dependent on trade flows from neighboring areas, as a landlocked area that is more than 1,300 km away (in the case of Maiduguri) from the main ports of Cameroon and Nigeria. Economic interdependence has historically manifested in strong (though largely unrecorded and informal) crossborder trade.[96] Trade flows straddle the Lake Chad region both from east to west and north to south. The region serves both as a transit corridor as well as a site of strong domestic trade in local (mostly agricultural) productions. Trade, however, has historically been informal in the region, with official trade figures tending to underestimate actual flows. A recent study, for instance, suggests that Nigeria exported more than 213,000 metric tons of nonfuel products to Cameroon annually, i.e. over forty times the official estimates.[97] The crossborder trade largely took place between the two largest cities in the area, N'Djamena in Chad and Maiduguri in Nigeria, across secondary cities such as Maroua in Cameroon and Yola in Nigeria, as well as between a growing number of smaller towns and market towns.[98] There are also important trade flows between Zinder in Niger and Kano in Nigeria. Official crossborder trade is the main source of public revenue collected locally for landlocked countries: tax revenue collected by customs funds most of the public services (including salaries of civil servants, in some cases).[99]

Regional integration through crossborder trade has been severely disrupted by road/border closures associated with the Boko Haram insurgency.[100] Both crossborder and inter-regional trade have been substantially affected by the conflict. In Nigeria and Cameroon, most trade took place through the corridor connecting Maiduguri in Borno State in Nigeria to Kousséri or Maroua in Cameroon's Far North Region.[101] The lack of border infrastructure also constrains crossborder trade. The only international city-to-city crossing is between Kousséri in Cameroon and N'Djamena in Chad; while most manufactured goods in Chad tend to arrive by road from Douala in Cameroon. Intensification of the conflict since 2009, as well as the

93 Magrin and Perouse de Montclos (2018).

94 Vivekananda et al. (2019).

95 The indiscriminate targeting of civilians appears to have been a major point of disagreement. The extremist group ISWAP avoids harming civilians, focusing mainly on military and government targets (Samuel 2019).

96 See Magrin and Pérouse (2018).

97 World Bank (2013a).

98 Magrin and Pérouse (2018).

99 This claim was made regarding landlocked countries: Chad, Mali, Niger and CAR, in contrast to Cameroon and Nigeria: "*le commerce transfrontalier est la principale source de revenus publics perçus localement: les recettes fiscales collectées par les douanes alimentent la majeure partie des activités des services publics (y compris les salaires des fonctionnaires dans certains cas)*" WCO (2018).

100 WFP (2016a, 2016b).

101 Magrin and Perouse de Montclos (2018).

closing of land borders in Nigeria since 2019, and the state of emergency declared in Diffa and the Lac region in Chad also in 2019 disrupted this trade flow. Banditry and armed attack threaten the trucking routes, reducing the circulation of vehicles. In the few places where physical border control exists, 'thick borders' arise due to conflict and insecurity[102]—suicide bombings occur regularly by pedestrians heading to the market, drivers of taxi motos, even by children entering schools. Since Boko Haram and its splinter groups tend to be viewed regionally as a Nigerian problem, security and surveillance are largely concentrated along terrestrial borders with Nigeria.[103]

Conflict and insecurity in the region have also raised the cost of regional trade. A survey of 305 transporters undertaken on behalf of the World Food Programme in 2016 found that banditry and insecurity became the main cause of concern for transporters in two of the four countries and the second constraint in Cameroon and Niger behind road infrastructure, which also ranks high in Chad and Nigeria, offering a reminder that transport was never easy in the region.[104] The same survey found that, with the crisis, supply routes for cereals in Borno State became subject to a particularly high number of checkpoints (every 15 km) and a high total amount of payments, as in other regions, such as Diffa in Niger. Country policy decisions also continue to interfere with trade such as the recent decision by Cameroon to ban exports of cereals to neighboring countries.[105]

Conflict has significantly shifted the pre-crisis trade routes. A study for the Lake Chad Governors' Forum discusses the resulting shifts in trade patterns.[106] The use of major roads in the Borno State has been restricted[107], with the situation only partially improving since 2015. The overall volume of traded goods and services appears to have declined. However, alternative functional trade routes emerged.[108] In these, trade has shifted away from the Borno State to safer courses through Niger and Cameroon.[109] These routes, however, are often costlier in terms of time and distance.[110] Displacement of trade also has complex effects in terms of redistribution of economic activities. The corridors between Nigeria and Cameron South of the Far North Region in Cameroon will benefit from the increased activity that has left the corridors of with Maroua and Kousséri. On the other hand, the displacement of cattle herds to the Adamawa and Northern regions of Nigeria and Cameroon, fleeing insecurity in the Far North (and conflict in English-speaking regions), create potential source of conflict between farmers and herders as competition for resources increases.[111]

In addition to the direct negative impact of Boko Haram on regional trade, counterinsurgency measures adopted by the governments—such as border and market closures—have also stymied the movement of people and goods in the region.[112] Douala is the closest maritime port to the capital city of N'Djamena, with approximately 79 percent of imports passing through the

102 Porous borders attract informal cross border trade (ICBT) both to save on customs duties and to avoid security forces concentrated at official crossings to check vehicles and inspect declared goods. When ICBT shifts to open land and nighttime crossings, insurgents often follow, looking to extort protection payments or confiscate goods. It is argued that the frequency of border attacks by insurgents may also be stimulated by the absence of security forces, due to poor resource allocation and funding.

103 WCO (2018).

104 WFP (2016a, 2016b).

105 Data on Cameroon, FEWS NET (Famine Early Warning Systems Network) (dashboard), FEWS Net, Washington, DC, https://fews.net/.

106 Caestens (2019).

107 An estimated 750 commercial vehicles were attacked by armed groups mainly in Borno (Mercy Corps et al. 2017).

108 Sissons and Lappartien (2016) report that traders had to take alternate routes instead of the direct 125 km route between Diffa and Maiduguri, the main market for red pepper in Northern Nigeria, resulting in an increased distance of 430 km for traders (in the best of case).

109 Two of these routes suitable for crossborder exchange are between Yobe State in Nigeria and Diffa in Niger (Geidam/Nguru – Diffa) and between Adamawa State in Nigeria and Garoua in Cameroon (Yola/Mubi – Garoua).

110 World Bank (2018).

111 Data on Cameroon, FEWS NET (Famine Early Warning Systems Network) (dashboard), FEWS Net, Washington, DC, https://fews.net/.

112 Magrin and Perouse de Montclos (2018).

port.[113] However, the deteriorating security situation on the Northern segment of the Douala-N'Djamena corridor has been a serious concern for transport operators, who have explored the use of alternative transport routes. The road that avoids the Far-North of Cameroon, going through the Chadian territory has gained interest and traffic, and the Chadian authorities and their developing partners are considering upgrading the road.[114] Instead of going from Ngaoundéré via Garoua and Maroua (Cameroon) to N'Djamena, the new corridor would run from Ngaoundéré East to Koutéré (Cameroon) and then continue North to Moundou (Chad) and N'Djamena (about 600 km). Parts of the road still need to be reconstructed or rehabilitated to make this alternative branch capable of sustainably handling the substantial increase in traffic.

While crossborder trade has decreased as consequence of conflict, it shows signs of resilience, including through the strength of social networks. The extent of economic interdependence among the different areas of the Lake Chad region is manifested in (mainly unrecorded) strong crossborder trade. While the volume of goods and services traded has been impacted by the security situation, some trade routes remain functional and new ones have emerged, as outlined above. The networks of family relationships, inter-connected border communities, and local alliances have bypassed many of the official restrictions on trade and movement of people, as well as conflict areas, and so borders in the Lake Chad region remain relatively permeable. The social structure of local traders has been noted as beneficial to their adaptation to the conflict, including by negotiating new trade routes with state officials. For example, Bol traders in Chad routinely send someone to foreign ports or cities to trade on behalf of other traders, and they consolidate their cargoes by means of transport. When the presence of Boko Haram led to the end of the circulation of boats on Lake Chad, Chadian traders went to the Niger customs to negotiate the way in which their goods—which would now transit through Niger on their way from Nigeria to Chad—should be declared.[115]

Enhanced crossborder trade can have positive effects on income and employment, particularly if it builds on the existent strong informal trade. Crossborder trade provides basic needs to populations living far from capital cities and national points of entry. People living in the areas surrounding Lake Chad are characterized by having strong trade, ethnic, cultural, and political ties, making these administrative areas economically interdependent. Exploiting opportunities for crossborder trade is likely to have a direct impact on incomes and employment in the region, particularly if the extensive informal trade relations can be capitalized on. The growth of regional value-chain, especially in agricultural products and food processing, could be a key mechanism for enhancing economic opportunities within the region and beyond. Currently, poor trade facilitation and weaknesses in institutions, regulations, and monetary policy management exert significant costs on intraregional trade in some countries. For instance, the trucking industry in West and Central Africa is characterized by the presence of cartels offering high prices and low service quality.

Smuggling is commonplace in the Lake Chad region. Smuggling tends to occur in border zones, particularly where varying levels of subsidies and tax regimes exist between borders. One of the forms of contraband is based around the subsidized price differentials of commodities between oil-producing states and their neighbors, in the form of trade from North African states to communities along their southern borders in Chad, Niger and Mali.[116] Illegal smuggling has an added economic incentive where import duties are high, often the case in resource-poor countries neighboring large petroleum producers.[117] Even

113 Taniform (2014).
114 United Nations and World Bank (2018).
115 WCO (2018).
116 Shaw and Reitano (2014).
117 For descriptions of this dynamic in the Maghreb, please refer to Ayadi et al. (2014).

margins on licit consumer goods can be significant. Fuel sold in Nigeria is subsidized, which reduces its price and makes its trafficking to neighboring countries attractive. Fuel trafficked out of Nigeria is also sourced from millions of liters of crude oil either stolen or diverted to be refined in artisanal distilleries. This fuel feeds contraband, both nationally and regionally, to the neighboring countries.[118] Furthermore, smugglers of small quantities of black-market gasoline tend to be profiled as Boko Haram enablers and are detained or arrested.

118 Assanvo et al. (2019).

1.5 Climate Change and FCV challenges

More frequent climate anomalies—rising temperatures, and aridification in particular—are associated with a rise in conflict activities in the region.

Territorial underdevelopment—rooted in low economic density coupled with high distance and division (3Ds)—is intricately linked to another layer of risks that are characterizing the region: conflict and climate change (2Cs). On the one hand, suboptimal territorial development can be a direct source of fragility and conflict. A well-established body of literature exists that highlights the primary role that poverty and low economic development play in fueling conflict and instability.[119] On the other hand, conflict and fragility also perpetuate underdevelopment, the feedback loop that is commonly referred to as a conflict trap.[120] The ongoing conflict in the Lake Chad region can also be seen as a manifestation of long years of underdevelopment.[121] Furthermore, increasingly erratic climate conditions in the Lake Chad region have intensified competition for limited resources and triggered conflict and violence, which have in turn stymied the economic progress of the region.[122] As highlighted in the analytical framework (Figure 1.1), it is this nexus between suboptimal territorial development and deepening fragility and climate risks that entrenches the laggardness of the region.

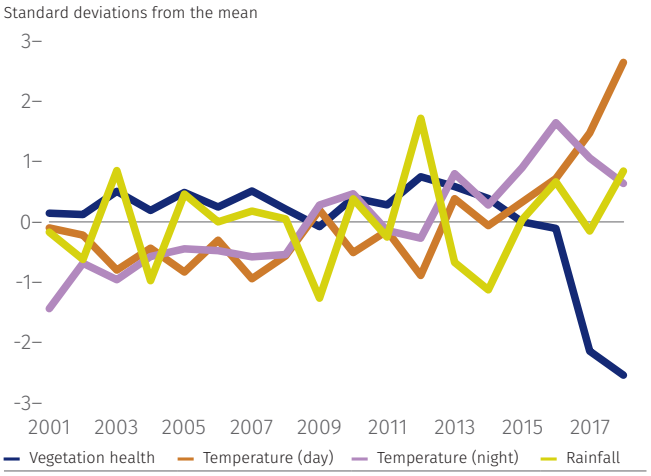
1.5.1 Climate Change and Harsh Environmental Conditions

The Lake Chad region has historically been subject to various climatic and environmental risks, such as recurrent droughts, rising temperatures and increasingly erratic rainfall patterns. Between the 1960s and the mid-1990s, the Lake Chad shrank due to severe and recurrent droughts, which resulted in lost economic opportunities and displacement of people in search of new ways of life.[123] Looking at patterns of climatic conditions over the past two decades, there is a sign of rising temperature in the Lake Chad region (Figure 1.14).[124] Across the Sahel, temperature is increasing 1.5 times faster than the global average. Furthermore, temperature is predicted to increase by 0.65–1.6°C and precipitation is estimated to decrease by 13–11 percent in the next two decades (that is, 2016–2025 and 2026–2035) relative to 1961–1990.[125] Analysis of patterns in the standardized precipitation-evapotranspiration index (SPEI)—which measures the extent to which the amount of rainfall in a given location deviates from its historical average after taking into account the ability of the soil to retain water—reveals that rainfall shortages appear to be increasingly common in the Lake Chad region (Figure 1.15).[126] These increasingly erratic climate conditions are making the livelihoods of people in the Lake Chad region more uncertain and vulnerable.

Increasingly erratic climate and its impact on the hydrology of the lake present a significant risk to livelihoods and food security across the region. The

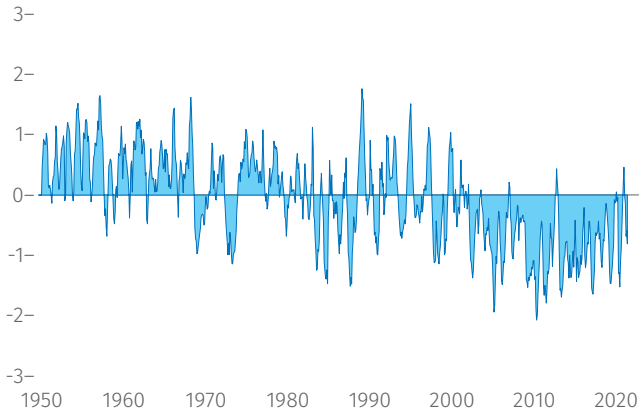
119 See, for instance, Hess and Orphanidis 1995; Collier and Hoeffler 2002; Collier et al. 2003; Fearon and Laitin 2003; Sambanis 2004; Blomberg et al. 2006.
120 Collier et al. 2003.
121 Tayimlong 2020.
122 GEOGLAM 2020.
123 Vivekananda et al. (2019).
124 The results presented in this section come from Fisker (2021) "Conflict and Climate in the Lake Chad Region", technical paper for this report.
125 Mahmood et al. (2019).
126 The calibration period for the SPEI is January 1950 to December 2010.

Figure 1.14: Trends in vegetation health (NDVI), temperature, and rainfall, 2001–18



Source: Fisker 2021, technical paper for this report; normalized difference vegetation index (NDVI): MODIS (Moderate Resolution Imaging Spectroradiometer) (dashboard), Terra, National Aeronautics and Space Administration, Washington, DC, https://terra.nasa.gov/about/terra-instruments/modis; rainfall and temperature: WorldClim, https://www.worldclim.org/.

Figure 1.15: Trends in the Standardized Precipitation-Evapotranspiration Index



Source: Fisker 2021, technical paper for this report; SPEI (Standardised Precipitation-Evapotranspiration Index) (dashboard), Spanish National Research Council, Zaragoza, Spain, https://spei.csic.es/index.html.
Note: The figure shows SPEI values (6 months) over the past seven decades.

Lake Chad region contributes to the food security of 13 million people within a range of 300km, considering connections with regional towns[127] and the Sahel region as a whole, which relies on resources from Lake Chad.[128] Droughts and human activities appear to have altered the hydrology of the lake through stream flow modification and water diversion[129], contributing to the water scarcity and fragility of the region.[130] Droughts can challenge agricultural production (in addition to being linked with increases in violence against civilians).[131] The fluctuations in inter-annual and seasonal water can also impede the development of stable resources exploitation rights and the administrative management of a transboundary resource.[132] Uncertainty over the timing, longevity, and strength of rainfall has coincided with increasing temperature and wind speeds.[133] These shifts are making it more difficult to understand what land is suitable for agriculture and pastoralism, and to sustain fish catches. Individuals that rely on the lake for income generation are unsure of what crops to specialize in, and when to switch from one occupation onto another.

Climate conditions are key determinants of local economic growth in the LCB countries where agricultural remains the most dominant economic sector. Climate conditions play an integral role in determining local economic growth particularly in agrarian areas whose livelihoods rely critically on weather conditions. Between 1992 and 2013, higher-than-normal rainfall amounts had greater positive effects on local economic growth in areas that are largely agrarian (and dependent on rainfall) as indicated by a positive interaction term between the SPEI and cropland density (see Figure 1.12). These findings suggest that the impact of climate shocks is not spatially uniform. Thus, assessing the potential risks that erratic weather conditions may pose to local agricultural economies need to be carefully evaluated.

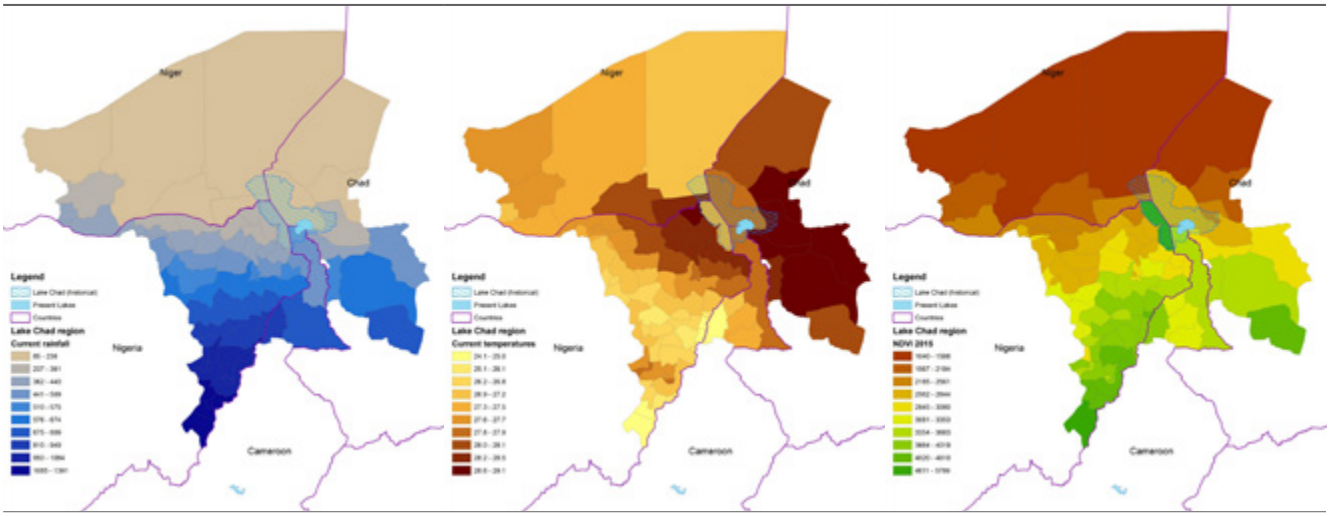
127 Galeazzi et al. (2017).
128 United Nations and World Bank (2018).
129 Lemoalle et al. (2012).
130 Okpara et al. (2015).
131 Begozzi et al. (2017).
132 Sarch (2001).
133 Vivekananda et al. (2019).

1.5.2 Links between Climate Variability and Conflict

Conflict dynamics and climate change are closely interlinked in the Lake Chad region. There is a well-established body of literature showing the link between violent conflict and climate change. Rising temperatures and increasingly erratic rainfall patterns due to climate change reduce the opportunity cost of fighting by lowering agricultural productivity, weakening state capacity by tightening its fiscal envelope, and intensifying resource competition through displacing people.[134] In the Lake Chad region, increasingly erratic climate conditions are also directly linked to conflict events.[135] As shown in Map 1.15, the Lake Chad region is home to a variety of different climate conditions. A large swath of lands in the northern parts of Niger and Chad is characterized largely as a desert, with little annual rainfall. Conversely, the southern parts of the region are home to more vegetation (as indicated by higher values in NDVI), enjoying higher annual rainfalls. These climatic conditions are closely linked to conflict proneness. Based on remote sensing data, the analysis shows that higher-than-usual temperature/rainfall and lower-than-usual agricultural productivity (proxied by greenness) lead to an increase in conflict activity.[136] For instance, a positive temperature anomaly of one standard deviation is associated with a 17.6 percentage point increase in the yearly number of conflict events taking place in a given district (at the second level administrative unit). Conflict events are also more likely in areas that experience lower-than-usual levels of greenness, measured by the NDVI (which also means lower agricultural productivity). Here, a negative anomaly of one standard deviation leads to an increase in the number of conflict events of 8.9 percentage points. The effects of climate factors on violent conflict are particularly pronounced in areas that are largely agrarian and more densely populated.

Increasingly erratic climate conditions make communal violence more likely. For example, in Cameroon, livestock transhumance-related conflicts between farmers and pastoralists are an increasing concern in the country's Far North Region. Between November and December 2020, the International Organization for Migration registered more than 320 transhumance conflicts. Insecurity and climate variability have forced shifts in the seasonal migratory routes of transhumant

Map 1.15: Average rainfall, temperatures, and greenness (normalized difference vegetation index)



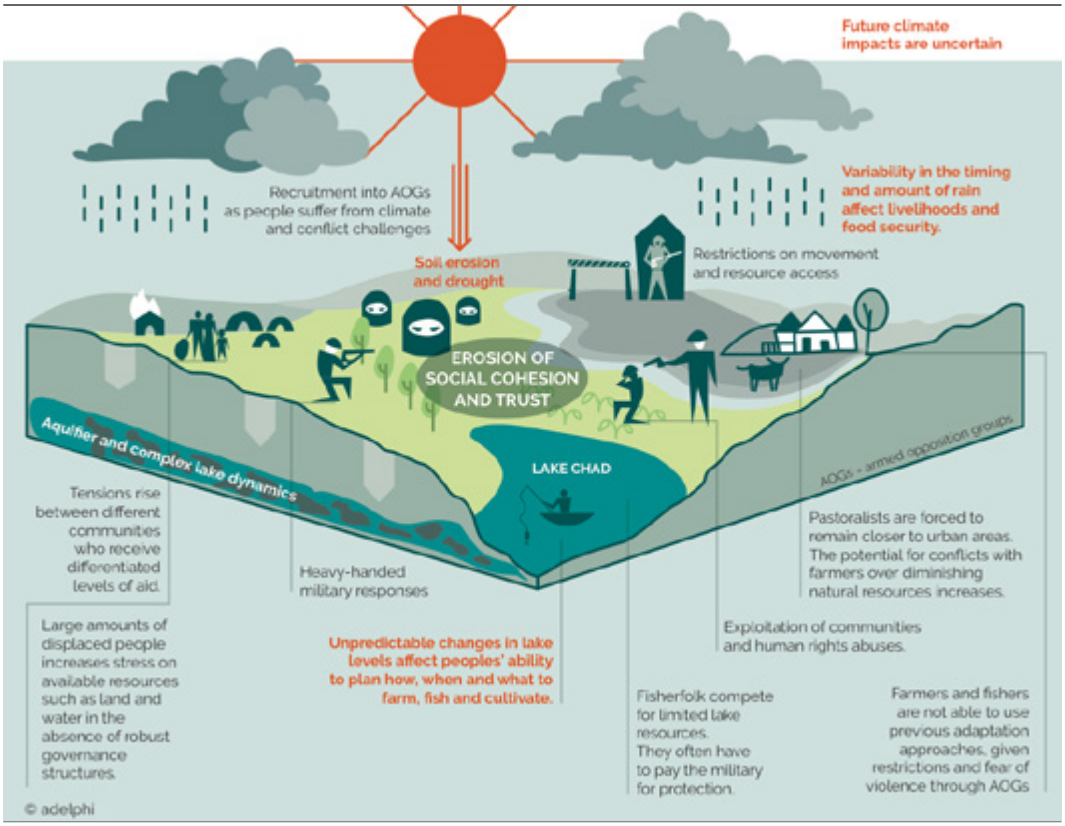
Source: Fisker 2021, technical paper for this report.

134 See Burke and Leigh (2010); Brückner and Ciccone (2011); Chaney (2013); Eberle et al. (2020); Fetzer (2020); Harari and La Ferrara (2018); Hidalgo et al. (2010); Miguel et al. (2004).

135 Onuoha (2014); Vivekananda et al, (2019).

136 The results presented in this section come from Fisker (2021) "Conflict and Climate in the Lake Chad Region", technical paper for this report.

Figure 1.16: The climate-conflict trap



Source: Vivekananda et al. (2019).

movements, which in turn, contribute to fuel the crisis. The International Crisis Group (Africa Briefing 105) has argued that "There is a danger that traditional transhumance will make the crisis worse than it would otherwise have been." These community-based conflicts have led to the formation of militias to protect resources (as well as to offer protection from armed groups), who are then drawn into conflict themselves.[137] That said, while it is a potential source of conflict, however, greater mobility can also be a source of resilience, allowing people to move toward available resources, regulating social pressures and generating income by facilitating trade.

Communities in the Lake Chad region are vulnerable to a "climate-conflict trap." The size and frequency of extreme and more intense weather events in recent years in Lake Chad is increasing livelihood insecurity and natural resource conflicts and decreasing the coping capacity of individuals and communities to deal with shocks. People are caught between extremes—conditions are too wet or too hot and dry—and those already escaping from violence may be uprooted again by droughts or floods. Agriculture and fishing activities that support most people in the Lake Chad region are increasingly subject to weather shocks, soil degradation, and livestock diseases. Projections indicate that weather conditions will only become more extreme and unpredictable. Moreover, conflict hinders the ability of communities in the Lake Chad region to adapt to climate change, creating a climate-conflict trap that has "fragmented social bonds among families, among

137 In Cameroon, the Central African Republic, Mali and Northern Nigeria, militia groups originally created for self-defense have played a strong role in driving conflict (ICG 2018; United Nations and World Bank 2018).

generations, among ethnic groups and between displaced people and host communities, making it harder for people to cope with and adapt to climate impacts than in the past."[138]

Together, conflict and climate change pose a direct threat to territorial development, and vice versa. Climate change has made weather increasingly variable within the Lake Chad as well as in the surrounding countries. The highly volatile security situation created by Boko Haram, negatively associated with the pace of local economic growth, poses another significant economic threat. Mitigating security and climate risks should remain among the top priorities for ensuring sustainable growth in the region.

1.5.3 The Social and Economic Effects of Conflict

The Boko Haram insurgency has caused a rapid—and lasting—decline in the level of economic activities across the region, particularly affecting less developed and less connected urban areas.

Despite government efforts to establish peace and stability, the number of conflicts and conflict-related fatalities has been on the rise in the Lake Chad region. Historical marginalization, exclusion from centers of power and decision-making processes, and a persistent lack of access to services are all structural drivers of fragility in the region, which have made fertile ground for the emergence and expansion of Boko Haram.[139] The Armed Conflict Location & Event Data Project (ACLED) (Raleigh et al. 2015) records four different types of conflict: battles, riots, protests and violence against civilians. Based on these data, the findings presented here show that the number of conflicts has increased across all types of conflict in the region, particularly since the rise of Boko Haram in 2009.[140] The number of fatalities from conflict follows a similar pattern. Fatalities began to increase since 2009, and peaked around 2014 and 2015, at around 1,000 per year, before plateauing from 2016 onward (Figure 1.17).

The decade-long Boko Haram insurgency, which first rose in Northeastern Nigeria, has taken a devastating humanitarian toll in the Lake Chad region. The region has 2.7 million internally displaced people, 257,000 refugees, and 5.3 million people who are facing severe food insecurity as of 16 September 2020.[141] While other conflicts exist in the area[142], the Boko Haram insurgency has been among the chief drivers for a record level of forced displacement in Nigeria and the Lake Chad Basin.[143] Assuming that displaced people do not return to their places of origin, the accumulated cost of displacement between 2013 and 2022 would be around N465 billion (US$2.3 billion), even if further displacement were to be stopped. According to the Food and Agriculture Organization of the United Nations, nearly 50 percent of the population in the Diffa region in Niger is in need of humanitarian assistance, and nearly 20 percent are facing issues of food security.[144] In the case of Nigeria, per the same report, nearly 70 percent of the population living in areas near the lake is in need of humanitarian assistance, with 43 percent facing issues of food insecurity.

The Boko Haram conflict has also eroded the social fabric of the Lake Chad region. The negative impact of the violent conflict on women and youth tends to be disproportionate on these groups' higher existing

138 Vivekananda et al. (2019), p.10.

139 A lack of state presence in the region and elite capture have been associated with the rise of the insurgency: "The group itself is an effect and not a cause; it is a symptom of decades of failed government and elite delinquency finally ripening into social chaos," (Felter 2018; Mahmood and Ani 2018).

140 The results presented in this section come from Fisker (2021) "Conflict and Climate in the Lake Chad Region", technical paper for this report.

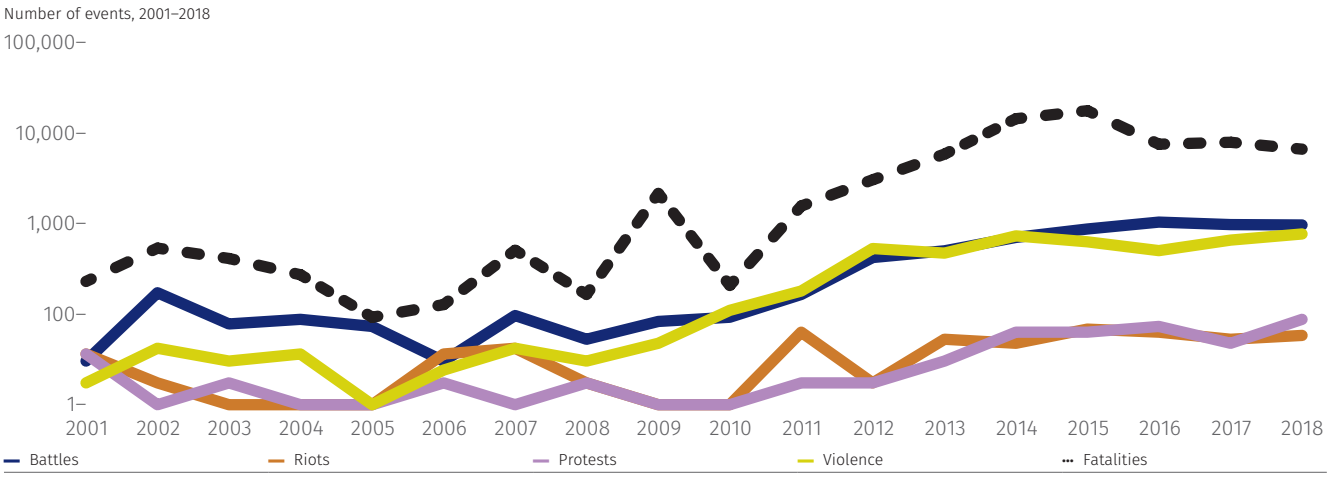
141 OCHA (2020).

142 Notably in Burkina Faso, Sudan, the Central African Republic and Mali.

143 UNHCR and World Bank (2016).

144 FAO (2017).

Figure 1.17: Conflict events and fatalities over time across the Lake Chad region



Source: Fisker 2021, technical paper for this report.

vulnerability.[145] The conflict has also reinforced distrust, whereby people are wary of anyone who may be former or active Boko Haram combatants. It has eroded social cohesion between groups following kidnappings and attacks against entire villages, as well as within villages, where the families of members of Boko Haram reside among other people. Heavy handed counter-insurgency measures have also contributed to the erosion of social cohesion and trust in the State, limiting future rebuilding efforts by governments.

Violent conflict and insecurity have also taken a significant toll on the regional economy. The level of violence in the region has intensified since 2009 when state security forces killed 800 of Boko Haram members, including its founder M. Yusuf.[146] At its peak (2015), the group seized a large swath of territories in Northeastern Nigeria, including major cities. The conflict has led to the disruption of economic activity and social networks, as well as the destruction of private and public assets.[147] The Institute for Economics and Peace put the annual cost of violence in 2019 in Cameroon, Chad, Niger, and Nigeria at 6 percent, 7, percent, 8 percent, and 8 percent of GDP, respectively.[148] Between 2011 and 2015, the northeastern part of Nigeria—one of the most affected regions—suffered an estimated accumulated output loss of N1.66 trillion (US$8.3 billion).[149] In 2015 alone, close to 800,000 individuals in the same subregion lost their income as a consequence of the forced displacement caused by Boko Haram.[150] This resulted in estimated losses of about N90 billion (US$250 million).

The rise of Boko Haram has had significant negative spill-over effects undermining the economies of neighboring countries. The reduction in nighttime light could be as high as 20 percent in areas within 200 km from the epicenter of the conflict. It was not until 2014 that Boko Haram expanded more formally

145 For example, higher exposure to the risk of violent extremism and criminal activity in the context of high youth unemployment; or increased risk of gender-based violence.

146 Kimenyi et al. (2014).

147 Vivekananda et al. (2019).

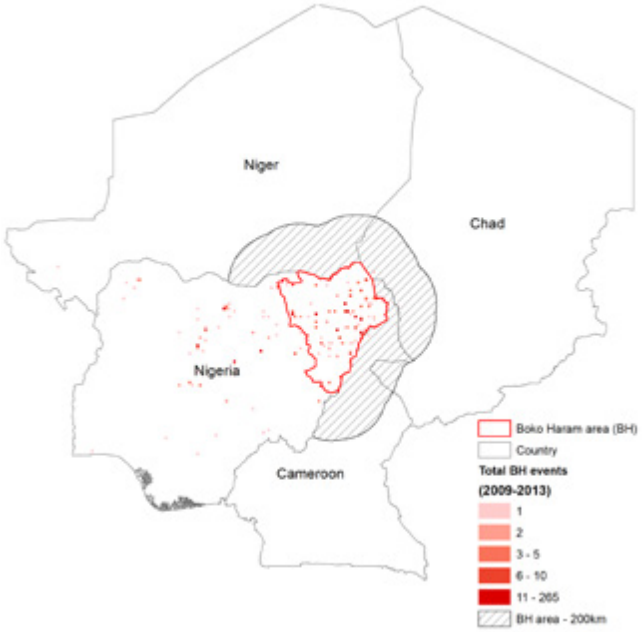
148 Estimates include direct and indirect costs of violence. Direct costs of violence are those costs to the victim, the perpetrator, and the government (e.g., military and medical expenditure and cost of policing). Indirect costs of violence are those that accrue after a violent event takes place, and include indirect economic losses, physical and psychological trauma to the victim, and loss of productivity. Estimates exclude spillover effects from conflict and violence, cost of crime to business, judicial system expenditure, domestic violence, and out-of-pocket spending on safety and security by households. Estimates are conservative and should be taken with caution given these exclusions. Methodology includes 19 variables across three domains: 1) Violence Containment; 2) Armed Conflict; 3) Interpersonal and Self-Inflicted Violence. IEP (2020).

149 See World Bank (2015b). Within the region, Borno State suffered from the largest loss in output, which fell by N708.18 billion (US$3.54 billion).

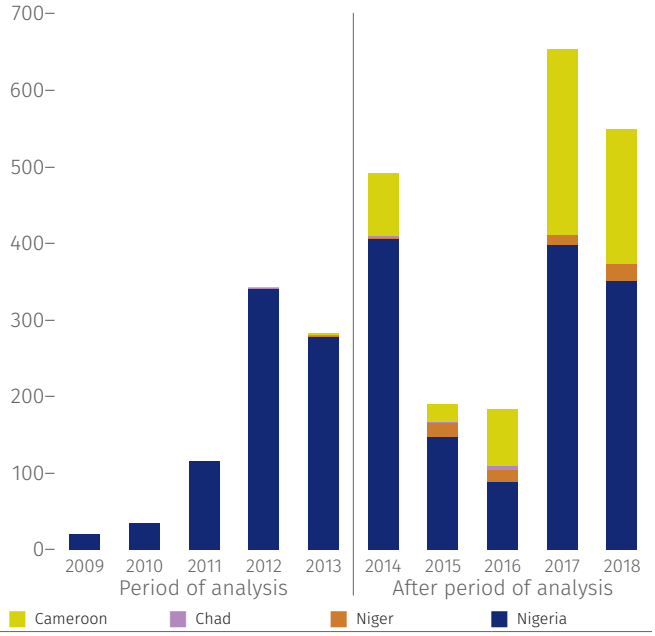
150 Pardo and Rossiasco (2016).

Map 1.16: Boko Haram Conflict in the Lake Chad region

a. Boko Haram Area and the Three Countries of Study



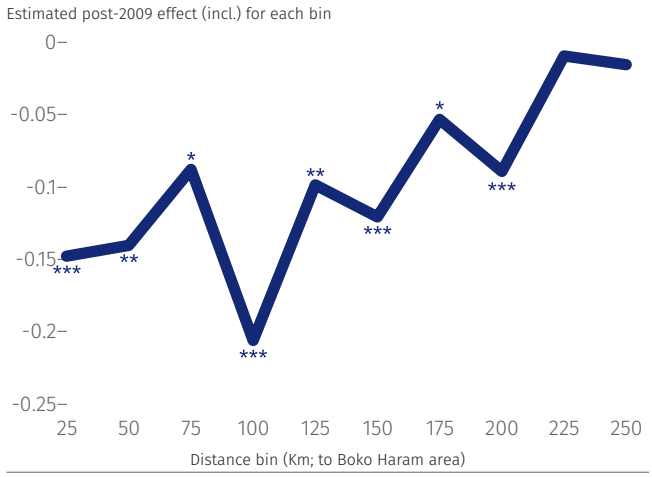
b. Number of Boko Haram Events, 2009–2018



Source: Jedwab, Blankespoor, et al. 2021, technical paper for this report.

its terrorist activities outside Nigeria and into the territory of Cameroon, Chad, and Niger (Map 1.16, Panel B). Yet between 2009 and 2013—years for which temporarily comparable data on nighttime light are available—proximity to the Boko Haram conflict was already strongly associated with relative declines in local economic activities in Cameroon, Chad, and Niger. The analysis indicates that there is a significant effect of Boko Haram in urban areas within a range between 25 and 200 km from the insurgency's activities. The average effect within 50 km suggests that the rise of Boko Haram reduces nighttime light luminosity by 15 percent. The effects for 50–100 km, 100–150 km, and 150–200 km are -15, -11 and -7 percent, respectively. Within the 200 km range, the effect suggests an average decrease of -12 percent (Figure 1.18). These negative spillover effects persisted and became even larger post-2013, reaching -35 percent by 2015 and -50 percent by 2018.

Figure 1.18: Boko Haram effects by distance to the Boko Haram area post-2009 (Incl.)



Source: Jedwab, Blankespoor, et al. 2021, technical paper for this report.
Note: The figure shows the post-2009 Boko Haram effect for each distance (to the Boko Haram area). Bin 25 corresponds to 0–25 kilometers; bin 50 corresponds to 25–50 kilometer, and so on. $^{*}p < .10$ $^{**}p < .05$ $^{***}p < .01$

The negative spillover effects of Boko Haram activities are particularly significant in urban areas initially less developed and less connected to other markets. The opposite is true for more connected towns. Negative effects were not seen in urban areas that initially had relatively more robust economies (as measured in nighttime light intensity) or that had better access to other major markets. The fact that those areas were more resilient and less affected by the Boko Haram conflict is

likely due to their more diversified economies and their ability to trade with markets other than those in Northern Nigeria, which became inaccessible with the conflict.

Conflict has significantly disrupted production in the primary sector in the Lake Chad region. In Cameroon, after Boko Haram extorted farmers in the lake area as a source of revenue, the army banned the production of millet and maize (including in certain nonborder areas), which led to a decline in the agricultural production of cereals and to displaced farmers.[151] Estimates suggest that, crop yields in Northern Nigeria could have been down by 50 percent or more at the height of the conflict, compared with pre-Boko Haram times.[152] In Chad, cereal production in 2016 was 11 percent lower than in the previous year; while in Cameroon it fell by 25 percent in the Far North Region.[153] The World Food Programme reports that the insurgency likely contributed to the reduction in the production of sorghum and millet in Adamawa, Borno, and Yobe states in Nigeria by forcing farmers to leave.[154] Fishing activities constitute an important source of employment and income in the region with an estimated value of US$54 million to US$220 million.[155] These activities have been disrupted by the insurgency looking for a source of revenue, as well as by the embargo from the Nigerian armed forces to stop the insurgents.[156] In the Diffa Region in Niger, the revenue of fishers selling smoked and dried fish fell from US$1,515 yearly before the crisis to US$420, that is, a decline of 72 percent.[157] The loss of mobility required to reach markets has also made for sizable trade losses.[158]

Many markets in the Lake Chad region have closed due to security concerns. The ongoing conflict poses significant challenges to economic activities including through the closing of markets. Map 1.17, below, provides a visual description of the number of markets in the region that have remained either closed or been operating at a low capacity.[159] Many markets in Northern Nigeria where most of the Boko Haram attacks took place, were not operating between 2014 and 2016. This was partly due to the Nigerian government's mandate for some markets to close given that these were frequent targets of Boko Haram attacks. Between 2017 and 2020, several markets on the fringe operated with a slightly below or normal status. However, markets in close proximity to Lake Chad were well below or not operating at all. More recently, in 2020, markets in Chad near the border with Cameroon and Nigeria were not operating.

Crossborder livestock trade has declined as a result of the insurgence. Conflict has affected production and trade directly, as well as indirectly, through the counter-insurgency measures that restrict movement and put bans on farming and trade.[160] Transit flows of livestock seem to be declining. The transit of cattle to Nigeria from Chad and Cameroon decreased by 39 percent between 2015 and 2016–2017, as shown by customs data from the Yagoua livestock crossing point.[161] The deteriorating

151 World Bank (2018).

152 Macaulay (2014).

153 FAO (2017).

154 WFP (2016a, 2016b).

155 FAO (2017).

156 FAO (2017).

157 Oxfam (2017).

158 An anecdotal, yet common example of market and petty trade disruption refers to the Baga fish trade, with an estimate value of US$19 million in annual sales in 2001. Given its profitability and strategic location as a border town on Lake Chad, Boko Haram insurgents overrun the fishing town twice, taking overfishing activities. The securitization response to Boko Haram included the implementation of administrative and security barriers to prevent the insurgents from benefitting from the large revenue stream. Fishing trade fell to a fraction of its previous levels. The security-related road closures also meant that those allowed to fish were not able to transport their fish to markets without military escort. The price of transporting fish increased from approximately N700 precrisis to around N2,000–N2,500 (UNDP 2020).

159 These results are taken from Blankespoor (2021), technical paper for this report.

160 UNDP and OCHA (2016).

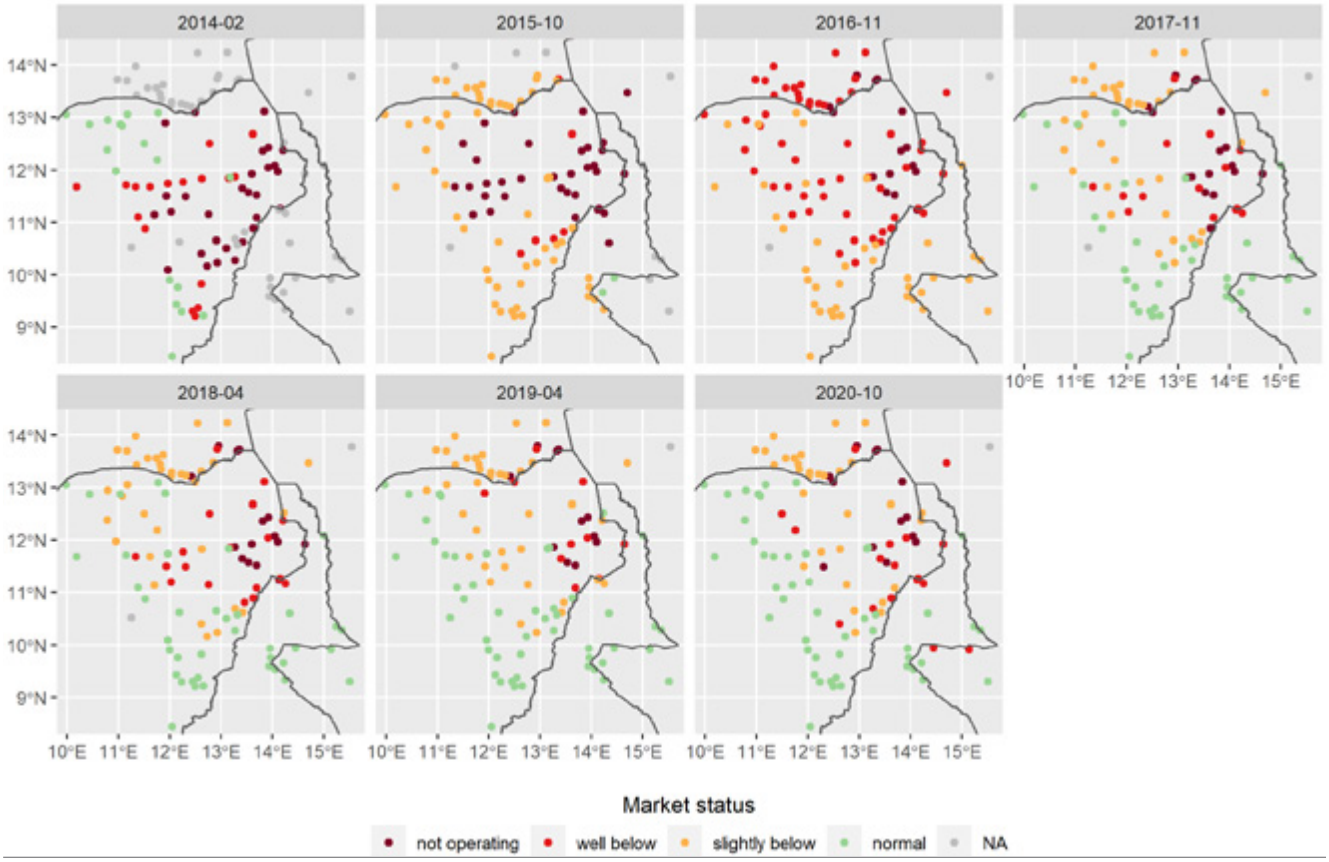
161 World Bank (2018).

impact that the conflict has had on Chad's livestock exports to Nigeria is even more poignant considering that these exports are the country's second source of foreign revenue after oil.[162] In Cameroon, estimates suggest that Boko Haram has stolen US$6 million worth of cattle, sheep, and goats since 2013.[163] Market infrastructure has also been subject to physical damage. For example, in Damaturu in Yobe, Nigeria, over 650 shops have been reported to have been damaged.[164]

Border crossings have been significantly reduced due to the heightened insecurity situations surrounding the region. Farmers in Cameroon who previously exported crops to markets in Northern Nigeria have had to find alternative destinations for exports within their own country. Restricted access to key strategic trade centers in Northern Nigeria (for instance, Baga in Nigeria) have posed a significant loss for people in the region whose livelihoods depended critically on crossborder trade (Map 1.18).[165]

Insecurity and restrictions on trade are also affecting prices, exerting upward pressure on food prices while depressing the price of tradeable such as livestock. Security measures, such as the banning of large vessels in Lake Chad by the Chadian government led to an

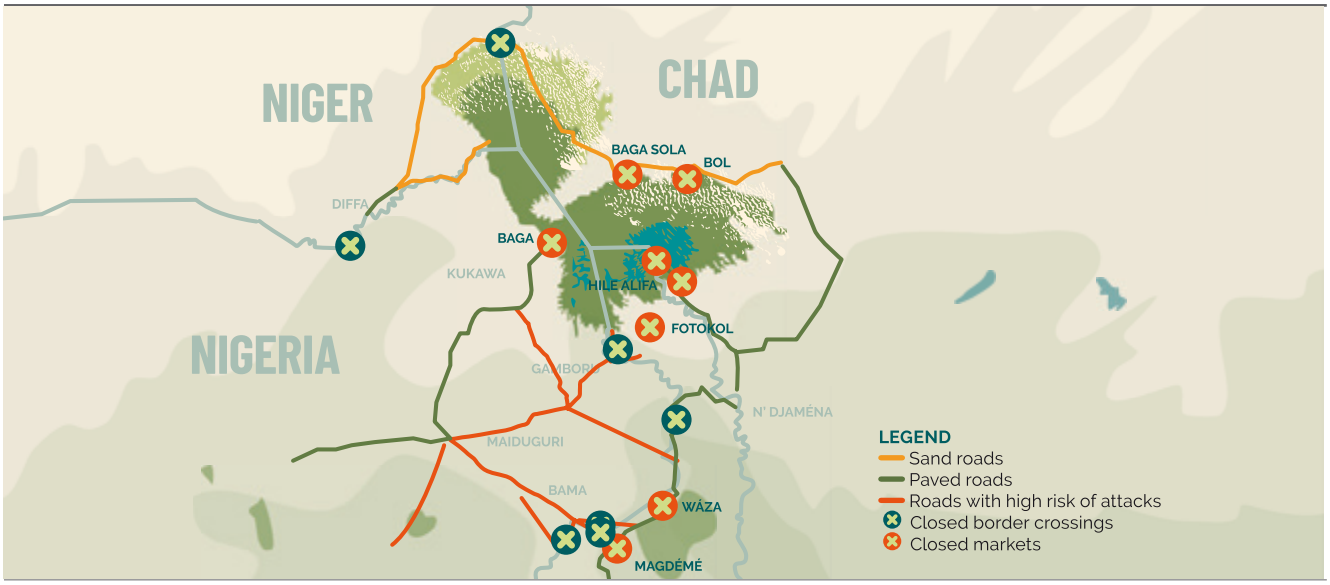
Map 1.17: The evolution of market status in the Lake Chad region, 2014–20



Sources: Blankespoor 2021, technical paper for this report; data of FEWS NET (Famine Early Warning Systems Network) (dashboard), FEWS Net, Washington, DC, https://fews.net/; Van Den Hoek 2017.
Note: This panel set of maps shows trends in market status in and near Nigeria's North East, with a selection for each year from 2014 to 2020 during the same month of the publication of the report.

162 World Bank (2015a).
163 World Bank (2018).
164 Mercy Corps et al. (2017).
165 Vivekananda et al. (2019).

Map 1.18: Restrictions on crossborder movement and trade



Source: Vivekananda et al. 2019.
Note: The map shows a selection of restrictions for illustrative purposes rather than a comprehensive assessment. The selection is based on field research. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by Adelphi or any of the funding parties.

automatic increase in the price of transport and goods. According to residents of the city of Bol in Chad, the price of basic goods increased by 30 percent since the ban on vessels came into force.[166] Data from the IMF show a surge in food prices and inflation in Chad, associated with lower agricultural production and security disruptions to the crossborder trade flows with Cameroon and Nigeria.[167] Prices in the northeastern part of Nigeria rose by 5.4 percent annually during 2011–15, while prices for food items rose by 7.5 percent annually.[168] Staple food prices in Niger are estimated to have risen steeply in the affected areas because of insecurity and the increased cost of transport.[169] At the same time, the inability to trade across borders is putting downward pressure on previously traded goods. The prices of livestock in Chad and Cameroon have dropped by 30 to 50 percent, given the countries' inability to export to Nigeria.[170]

Boko Haram also plays an active role in smuggling in the region. Like other terrorist groups in the Sahel, Boko Haram works in connection with local criminal groups to control smuggling routes around the Lake Chad Basin. The insurgency provides young people with motorcycles, expecting them to monitor the positions of the defense and security forces (DSFs), allowing Boko Haram to plan attacks or change the routing of contraband transfers as needed. The collaboration tends to be more transactional than ideological, and the proportion of recruited youth is small.[171] Nonetheless, for many youths in the Lake Chad region that lack economic opportunities, Boko Haram offers potential material and social advancement.[172]

166 Cantens and Raballand (2017).
167 IMF (2016).
168 World Bank (2015b).
169 WFP (2016a, 2016b).
170 FAO (2017).
171 Lierl (2020).
172 Gaye (2018).

1.6 Policy Options

The analyses collated in this regional economic memorandum present a comprehensive diagnostic of the Lake Chad region, taking as a basis the feedback cycle between suboptimal territorial development, on one side, and FCV, on the other. The memorandum shows that over the last decades, the Lake Chad region has displayed little progress in social and economic development, with areas around the lake trailing behind the rest of the basin countries in terms of poverty reduction, human capital indicators, and economic growth. Limited access to basic services as well as to markets, infrastructure, and economic opportunities—particularly for youth, women and vulnerable groups—has rendered people unable to accumulate and use assets productively. At the same time, the region has been stricken by violent conflict and harsh climatic variations. This intersection is at the heart of this memorandum, which poses that the lag in territorial development is as much an outcome as a driver of FCV. Specifically, the analysis shows how low economic density and high distance and division—the '3Ds'—interact with and potentiate conflict and climate change—the '2Cs'—in the region, with negative impacts on development outcomes, in a self-reinforcing cycle. Breaking free from this cycle toward an inclusive and stable growth path requires promoting territorial development as well as reducing systemic risks, strengthening governance, and improving service delivery (See Figure 1.1 in Section 1.2).

Longstanding challenges to territorial development partly explain the Lake Chad region's enduring poverty and sluggish economic growth. The region is characterized by low economic density and the absence of agglomeration economies, where urban areas are growing faster, with widening spatial gaps, and a lack of regional convergence. Connectivity gaps in the region are severe, particularly in rural areas, which limit people's access to markets and higher-quality jobs. The variability in the water level of Lake Chad—whose surface decreased significantly between the 1960s and mid-1990s but has started recovering since—had a permanent impact on local population growth, forcing people to migrate to urban areas. Both urban and rural settings, however, often lack access to basic services, infrastructure, and income-generating opportunities, particularly for women, youth, displaced people, and other vulnerable groups. The historically strong crossborder trade in the Lake Chad region was disrupted by the Boko Haram insurgency, which has become a source of social division in the region. The combination of low economic density, and high economic distance and division has contributed to prevent the region from realizing its potential as a diverse and vibrant agricultural and commerce hub, strategically placed within West-Central Africa, and to lay down foundations toward its structural transformation.

Violent conflict and climatic change are aggravating the region's territorial development challenges. The findings illustrate the interlocking links between climate change and economic progress and stability: from the negative effect of the variability in the level of Lake Chad on population growth and urbanization, to the more recent variations in rainfall, vegetation and droughts and their impact on driving violent conflict and regional instability. Areas near the lake have experienced a higher share of drought than other parts of the basin countries, putting livelihoods and food security at risk. Droughts and human activity appear to be contributing to the scarcity of natural resources, which in turn, is a trigger of conflict, notably among pastoralists and farmers. There are signs of a climate-conflict trap, suggested by the association between climate anomalies—such as rising temperature, and erratic rainfall—and violent conflict in the region. The Boko Haram conflict has affected agricultural production, limited mobility and hampered crossborder trade in the basin. In addition, the conflict has aggravated social exclusion, curtailing access to services and income-generating opportunities, and driven the forced displacement of people. The economic impacts are not limited to the areas directly impacted but have

spilled over to neighboring regions. The memorandum shows that less well-connected and developed urban areas are more affected by the conflict. This underlines the self-reinforcing link between economic geography challenges, conflict and suboptimal development outcomes. Policies with the potential to improve territorial development and reduce conflict and the impact of climate variations can help break the vicious loop that is making the region diverge from its long-term potential.

In this context, there are several policy implications that this memorandum offers. First, as an overarching matter, it is urgent to address insecurity and conflict and restore the rule of law in the Lake Chad region. Notwithstanding progress, violent conflict and insecurity continue to undermine the stability for the inhabitants of the region, and impede advancement in other development areas. Concerted and bold efforts are needed to secure peace as a first step to inclusive and sustainable growth.

A second implication of the analysis is that for the Lake Chad region to escape its vicious cycle of weak territorial development and fragility, actions on several fronts will be required. Looking for a single action or policy to act as an engine of security and development is insufficient. Addressing the challenges emerging from territorial development and leaving aside those related to FCV would risk maintaining the status quo. This is not to say that a single policy implemented in isolation will not have a positive development impact. Yet, when the objective is to dramatically alter the development dynamics in the Lake Chad region, a holistic and coordinated effort along different fronts has the most potential. In this context, a multisectoral approach for policy implementation, that uses complementary interventions, is needed to address the interaction between climate change, violence, and laggardness. For example, investments in local public goods and services can complement connective infrastructure. Improvements in transfer systems and local capacity can help strengthen the provision of local infrastructure and services. Easing the movement of goods and labor by reducing trade and information barriers can help facilitate trade. By building social cohesion, increased citizen participation can help restore government presence. And, coordinated resource management, information and technology transfer can help reduce divisions.

A third implication is that the needed interventions must generate a 'big push', strong enough to alter the existing dynamics in the region. Marginal interventions are unlikely to break or revert the self-reinforcing cycle that has kept the Lake Chad region in a suboptimal equilibrium. It is not that measures that go in the right direction will not have a positive impact on development outcomes, but rather, that these single interventions would be limited in what they can achieve given the complexity of the challenges involved.[173]

Fourth, it is important to identify entry points, or policy levers, that can help break or revert the cycle of weak territorial development and climate change and conflict. Breaking this cycle will require a concentrated focus on improved natural resource management and strengthened governance to reduce the high social and economic costs imposed by climate change and conflict. Interventions aimed at mitigating the negative effects of climatic risks can reduce the stress over the primary sector and other economic activities, but also reduce potential conflicts between pastoralists and farmers over diminishing land and water resources. These policies, coupled with interventions aimed at improving governance and service delivery in the region, can further reduce conflict and fragility to enhance economic prospects and improve the credibility and legitimacy of governments in the region. The poor stand to gain the most from a reduction in conflict since they

173 This is also well anchored in the World Bank's Crisis Response to COVID-19 and Climate Change, which, as discussed in the Development Committee Paper, lays out a broad framework for supporting green, resilient, and inclusive development (GRID) in IDA and IBRD countries. Integrated, longer-horizon GRID strategies are needed to repair the structural damage caused by COVID-19 and accelerate climate change mitigation and adaption efforts while restoring momentum on poverty reduction and shared prosperity.

are often the victims. Less conflict implies reductions in production costs, decreasing spending associated with protection and elevated transportation costs. A reduction in violence would also create stronger value chains, potentially contributing to an increase in trade and open space for other areas of economic activity to grow. It would also reduce out-migration from the Lake Chad region and incentivize migrants and displaced people to return and invest. These policies can lead to an increase in productivity for farmers, herders, fisherfolk, and micro and small enterprises, leading to overall territorial development.

The policy discussion, next, is organized around four crosscutting policy areas: infrastructure, trade, governance, and natural resource management. Policies and programs across these four dimensions, which are grounded in the analytical framework[174], would help strengthen territorial development and reduce FCV, thus helping the region to break free from its current low-growth and high-poverty trap. First, investing in infrastructure can help close connectivity gaps in the Lake Chad region, leading to higher productivity and better-quality jobs, particularly in rural areas. Second, enhanced trade and regional integration are associated with stronger agricultural value chains, higher incomes, improved food security, and greater stability. Third, enhancing governance at the local, national, and regional levels is crucial to strengthen the rule of law which is needed to mitigate the devastating effects of violent conflict on lives and livelihoods and to ensure the delivery of quality services (e.g., access to schools, health facilities, electricity, safe water/sanitation) that would promote social inclusion and reduce divisions. Finally, improved natural resource management, including more effective land and water management practices suited to local agroecological conditions, would help mitigate the negative impacts of weather shocks, natural hazards, and climate change on productivity and livelihoods.

The level at which policies are designed and implemented matters, as well as the understanding of the institutional function they are serving. The implementation of the following policy options would benefit from taking into consideration whether they are to be designed and implemented at the regional, national, subnational, or community levels. Actions with potential to enhance security, trade, and natural resource management (land, water, climate change) require regional coordination and cooperation. On other hand, while investments in human capital can have positive spillovers onto neighboring regions, improving service delivery and social protection mainly requires robust policies at the national and local levels (that can also help strengthen each country's social contract). Considering the different agents and tractions at play, including at the subnational level, are also key to define whether policies would be better implemented through a top-down or bottom-up approach. It is also useful to consider the three core functions of institutions—and the challenges they address—that can ensure that rules and resources yield the desired outcomes, notably: commitment, coordination and cooperation (Box 1.1). Under this lens, security could be viewed as a commitment problem, requiring the appropriate incentives whereby all parties stand to lose if they default on an agreed arrangement. Improved coordination between subnational governments—building on the region's crossborder ties—could help facilitate trade, potentially leading to a better equilibrium for all parties. The sustainable management of natural resources in Lake Chad and climate change mitigation, on the other hand, will likely require explicit cooperation, with checks and balances, between the four countries.

1.6.1 Connective Infrastructure

A strategy to promote economic agglomeration in cities in the Lake Chad region would need to consider establishing better links with rural areas. Density, in the form of economic agglomeration and/or urbanization,

174 Which draws elements from the World Bank (2003, 2009, 2010, 2011, 2013b, 2017).

Box 1.1: Three institutional functions—commitment, coordination, and cooperation—to increase the effectiveness of public policies

In insecurity settings, commitment is key to reach credible agreements. Commitment is achieved by establishing institutional arrangements that provide sufficient incentives for all key groups to work within the rules. The commitment is credible because all parties stand to lose if anyone reneges on those arrangements.

Coordination can also enhance policy effectiveness for security, growth and equity. For investment and innovation, agents must believe that others will also invest. Institutions can help solve market failures by coordinating both the investment decisions and the expectations of participants.

Finally, policies to achieve equitable development require cooperation. Among others, cooperation problems are often seen in the provision of public goods or solving environmental concerns related to overexploitation of natural resources. In coordination problems, multiple equilibriums exist, and policy is a matter of helping make the jump to the optimal one. Solving cooperation problems, by contrast, typically requires credible rewards or penalties to prompt actions that lead to the jointly preferred outcome.

Enhancing policy effectiveness

Designing policies to improve security, growth, and equity also requires understanding the balance of power among different actors. In the presence of powerful actors who can block or undermine policies, optimal policies from a strict economic standpoint (first-best policies) may not be the optimal implementable policies (second-best but feasible). Adopting an implementable second-best design could therefore be more effective than choosing the seemingly first-best but less-feasible policy.

Power sharing and resource redistribution can reduce exclusion and the incentives to engage in violence. Just as exclusion may lead to violence, mechanisms that encourage power sharing—such as legislatures that guarantee the representation of all groups—can reduce the incentives to engage in the use of force by raising the benefits of security.

Controlling clientelism can help solve problems related to delivering on redistributive policies. In clientelistic settings, the provision of public spending and services is often used for political purposes, for example favoring certain groups, while more vulnerable groups are excluded from resources. Mechanisms that control clientelism can enhance equity and make commitment to long-term objectives credible.

Source: Adapted from the *World Development Report 2017: Governance and the Law* (World Bank 2017).

is associated with economies of scale in production and an efficient accumulation of labor and capital, and thus with their potential for economic growth. A large share of the rural population in the Lake Chad region, however, is disconnected from the main road networks, making it difficult for people to benefit from the agglomeration that larger cities offer. Better links with rural areas can help low-density areas build up their economic densities or at least increase their proximity to urban areas. Firms located closer to each other can reduce transaction costs and facilitate the exchange of knowledge to improve productivity, with a higher concentration of jobs. Policy interventions that improve connectivity between rural and urban areas in the Lake Chad region can, in this way, promote the growth of cities and reduce marginalization. Agglomeration in cities would also facilitate public service

delivery, presenting possible savings in water, sanitation, electricity, and road infrastructure, as well as making it easier to monitor violence and insecurity, all of which are needed to spur economic transformation to boost inclusive growth in the Lake Chad region.

Investing in road infrastructure and connectivity is a priority for reducing economic and social distance and division. Economic and physical distance hinder the flow of capital, labor, and goods and services. Improving connectivity, both within the Lake Chad region as well as between the region and other areas of the respective countries, would improve welfare through more income-generating opportunities and better—and more equitable—service delivery (which can, in turn, help minimize social divisions). The evidence presented in this report suggests that access to a paved road is associated with diversification away from agriculture in the Lake Chad region. This is because roads enhance access to markets and competition from other locations. Improvements in connectivity can have a catalytic impact for improved access to basic services. New investments need to take into account existing infrastructure to take advantage of complementarities, and importantly, making sure that existing roads are safe to travel.

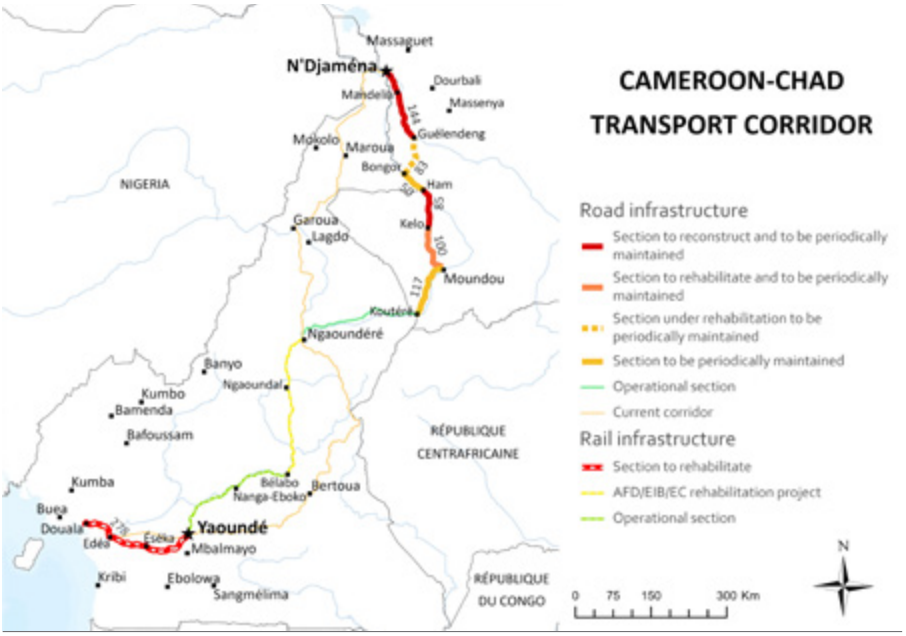
A connectivity strategy for the region needs to consider revitalizing damaged infrastructure and markets and investing in maintenance and security. Insecurity and poor road infrastructure make up the main impediments to trade and transport in the Lake Chad region. Revitalizing infrastructure can include the rehabilitation of roads that provide safe alternative transport routes. Box 1.2 describes an alternative Eastern branch of the Douala-N'Djamena corridor, which has the potential to become a more secure route (Ngaoundéré-Koutéré-Moundou) for transport operators. To enable this corridor, parts of the road would need to be reconstructed and/or rehabilitated to ensure that the route can handle a substantial increase in traffic—and subsequently be well maintained and monitored for safety, for which it is important to enhance mechanisms for coordination between local, national, and regional agencies. One risk, however, is that once the conflict is mitigated, traffic may not return to the previous branch (Ngaoundéré-Garaoua-Maroua). Cost-benefit analysis and risk assessments can complement the resources and technical expertise necessary to reconstruct damaged infrastructure and markets instrumental for re-launching regional trade.

Investing in digital infrastructure and improving access to electricity would significantly reduce distance and division. As discussed in the report, the Lake Chad region lags in terms of digital infrastructure, access to digital technologies, and access to electricity. Access to electricity, cell phone coverage and broadband internet infrastructure are drivers of economic growth, with the potential of higher wages due to the lower costs faced by workers and firms, increased earnings of firms and household enterprises, higher consumer surplus derived from lower prices, and higher quality of services. Unlocking private capital and competition to fuel expansion in digital and electricity connectivity, particularly in rural areas, hinges on governments building frameworks that promote private sector participation. For instance, public-private partnerships can help engage nonpublic actors to assume risks and increase the efficiency of infrastructure investments. For digital and electricity services, where cost recovery is possible, it is important to ensure cost-reflective tariffs across the region, and at the same time, leverage the regulatory capacity of national governments (e.g., through competition authorities) to ensure market contestability and improved service delivery. This is to say that investments in digital and electricity connectivity need to be accompanied by investments in institutional capacity.

Policies that support urbanization and agglomeration need to take into account associated risks and include mitigation measures. By increasing competition, urbanization and agglomeration could lead to aggravated social and communal divisions or entrenching patterns of exclusion in the short term. In Maiduguri, for example, the influx of refugees may have contributed to fuel segregation and communal tensions. Interventions that support urbanization and agglomeration could also be perceived as favoring 'settled' farming over nomadic pastoralism. The opportunities and risks of efforts to

Box 1.2: Alternative routing of the Douala-N'Djamena corridor

Almost 80 percent of Chad's imports enter the country through the Douala-N'Djamena corridor. The deteriorating security situation and attacks by Boko Haram on the Northern segment of the corridor are a serious concern for transport operators, who have explored the use of alternative transport routes to N'Djamena. In particular, a passage that avoids the Far North of Cameroon and runs on Chadian territory has gained interest and traffic. Instead of traversing from Ngaoundéré via Garoua and Maroua to N'Djamena, the alternative route would run from Ngaoundéré East to Koutéré and then continue North to Moundou and N'Djamena (see figure). In 2015 alone approximately 500,000 tons of goods passed through this corridor compared with 40,000 tons through the previous corridor.a Parts of the road still need to be reconstructed or rehabilitated to make this alternative branch capable of handling a substantial increase in traffic, but corresponding preparations and works are in progress.



Source: World Bank elaboration using ARCGIS Pro.

The new Eastern branch of the Douala-N'Djamena corridor would provide transporters with an alternative, more secure route to ship their goods to N'Djamena. This would help mitigate against the risk of Chad being cut off from international markets by the Boko Haram attacks in the Far North of Cameroon. On the other hand, the re-routing would drain traffic from the Ngaoundéré-Garaoua-Maroua branch, potentially depriving the population along the corridor of business opportunities. And, there is significant risk of a hysteresis effect. Once the risk of Boko Haram is mitigated and the Far North of Cameroon is safe again, it is unclear that all previous traffic would return to the Ngaoundéré-Garaoua-Maroua branch. The long-term effects of the emergency development of the Ngaoundéré-Koutéré-Moundou branch thus need to be assessed and mitigated to prevent the risk of further economic depression and isolation in the region.

Source: Walkenhorst 2021, technical paper for this report.

concentrate higher economic density of labor and capital may play out differently across time, with the benefits of agglomeration being realized in the longer term.

1.6.2 Trade Facilitation

The effectiveness and efficiency of economic and trade measures intended to counter Boko Haram must be regularly assessed, including at the regional level, as these measures often affect the livelihoods of export producers and traders. This includes considering ways to allow gradual and safe access to parts of Lake Chad to renew fishing and fish trading, and opening borders. Another important step is to re-evaluate the current restrictions on movement and access to farmland, balancing the need to contain and suppress Boko Haram with the desirability to restart the local economy. Leveraging spatial data would help in this regard. Crossborder agricultural trade can be a source of food security and resilience, where weather-and insecurity-patterns are not neatly confined to national borders, and often the closest source of food supply is across a border. Given the urgency to boost food security and restore commercial ties in the wake of COVID-19, it would be important that initiatives aimed at boosting trade build on the strong informal crossborder trade practices. Historic ties binding the region are a potential strength. Elements in the policy levers of trade could leverage the resilience of trade networks in the region—family relationships, connected border communities, and local alliances—and be designed with a view to better leverage this social capital (the same could also be applied in terms of natural resource management). In addition, an aim to manage the crisis, minimizing the potential for additional harm, can benefit from considering short, medium, and longer-term priorities.

Functional roads and markets are instrumental to recover regional trade and contribute to close divisions. There is a strong case to focus resources and technical expertise on reconstructing damaged infrastructure and markets, especially near or at borders that are instrumental for re-launching regional trade in the medium term. While complex to implement, another aspect that could bear benefits is contributing to ensure that local security forces enable roads that are passable to work properly as a route for the transport of goods, without excessive police roadblocks or red tape. Improved customs operations is key to revitalize long-distance trade corridors. In the immediate term, however, borders are closed, transport routes have been abandoned, and several markets have been disrupted or closed. In this context, it is important to provide support for communities that have been deprived of their traditional export production so that they can support infrastructure rehabilitation efforts.

A key step to recover regional trade is facilitating crossborder trade between the Economic Community of West African States (ECOWAS) and Central African Economic and Monetary Community (CEMAC) members, taking advantage of the opportunities offered in implementing the newly signed the Africa Continental Free Trade Area (AfCFTA). The four Lake Chad countries are members of different regional trading blocs: Cameroon and Chad are members of CEMAC and CEEAC (Economic Community of Central African States), while Niger and Nigeria are part of ECOWAS. This means that trade is not duty-free between the two blocs and trade regulations are not harmonized. For example, the import tariffs applied by Cameroon are generally higher than those charged on imports into Niger and Nigeria. Differences in tariff and taxes create incentives for trade diversion and smuggling. The recent signing of the AfCFTA agreement and its implementation would eliminate tariffs within the region and offer the opportunity to align other policies. Gains from trade facilitation, in particular, the reduction of nontariff barriers under the AfCFTA are expected to be large.[175] Trade facilitation and integration measures in the Lake Chad region could involve, among others, the visa-free movement of persons as well as the exemption for agricultural and livestock products and handicrafts

175 See World Bank (2020a).

of the requirement to be accompanied by a certificate of origin.[176] Complementary trade facilitation measures would also enhance the benefits of transport corridors. For example, reduced border frictions (smaller transport waiting times) would have positive economic effects, as shown in this report, including positive spillover effects on nearby countries.

Investing in economic infrastructure to support the collection of data on economic activity and trade can provide policymakers with a better information base. More and better data on traded quantities in markets and the sources of supplies could be collected and monitored, as well as more comprehensive and consistent market price data than those currently available. Novel data gathering techniques (e.g., remote sensing, border surveys, cell phone data records) would help better understand the complexity of trade and smuggling in the Lake Chad region, and how these are evolving. Priorities in this regard include improving the collection of information along points of entry/exit and trade routes, for instance by attaching geospatial data (locations, roads) to customs declarations, intelligence reports, and fraud cases.

Having substantive input from borderland communities for economic development strategies, including trade, can help with the sustainability of efforts. Research suggests that strict border controls negatively affect borderland communities, increasing unemployment, crime, and outmigration.[177] Rather than relying solely on security institutions as the dominant state representatives in borderlands, border security practices can benefit from increased participatory local governance and state-sponsored people-to-people dialogue at the border.

1.6.3 Governance

Restoring a positive state presence in the Lake Chad region is paramount. Improving the delivery of basic public services is a foundational aspect of restoring state presence, not only because of the need for basic services but as a cornerstone to start rebuilding government legitimacy in the region. Improved accountability and transparency of state structures are also necessary to rebuild government legitimacy, which can help improve—and sustain—security in the area. Addressing the attrition of public institutions can provide a better foundation for peace than a focus on a rapid exit from asymmetric conflict. Strengthened institutions that can create incentives both to reach agreements and to enforce them can create the foundations for peace and stability.[178] Promoting inclusive decision-making processes at the local level can help increase the participation of citizens in the development of their communities, which can also increase legitimacy and the sustainability of efforts. In some cases, effective state presence may also imply striking a balance between governments' decentralization processes while strengthening local governments to ensure they have the sufficient capacity to carry out their functions.

Increasing the opportunity cost of engaging in violence and providing economic opportunities to younger populations is needed to mitigate conflict. Engagement in decision-making structures can contribute to reduce youth vulnerability and exclusion, while better economic opportunities can discourage engaging in violence by increasing the relative opportunity cost of fighting. This report shows that droughts and abnormally high temperatures correlate with higher incidence of conflict possibly by lowering the opportunity cost of fighting. It is therefore crucial to provide alternative sources of livelihoods to people living in areas struck by heatwaves and droughts. In some cases, encouraging migration to

176 These measures are already part of the ECOWAS Trade Liberalization Scheme and could possibly be applied at ECOWAS-CEMAC borders on a reciprocal basis.

177 Ayadi et al. (2014).

178 United Nations and World Bank (2018).

urban or more fertile areas could be applicable (where recipient areas, with basic service provision and income-generating opportunities in place, have the potential to absorb migrants).

Another key aspect to mitigate the violent conflict is to restore social cohesion and trust between citizens and the state, as well as between communities. The Boko Haram insurgency in the region has led to the disruption of social bonds, the decline of social capital and the erosion of the social contract. Growing distrust, fear and anger toward people of different ethnic, religious and political persuasion and geographical origin, as well as toward those suspected of any association with the insurgency are being reflected in everyday life—such as in the avoidance of previously used markets.[179] Social divisions are also frequent among displaced people, who face barriers to integrate into local communities. There is evidence of discrimination and limited access to services (education, health care, social assistance, and access to land and livelihoods) in the region, including in urban areas that have grown rapidly and unplanned as a result of this displacement.[180] In parallel to the disruption of social bonds, the population has also lost confidence in the government's capacity to take effective public action, further eroding the social contract.[181] Both social divisions and loss of confidence in the government contribute to fuel the ongoing conflict.

Participatory and inclusive approaches can maximize the conditions to repair social divisions.[182] Supporting joint social, planning, and development initiatives between displaced and host communities can help reduce stigma and mistrust. Locally specific projects—that take into account the circumstances of vulnerable groups—and conflict-sensitive programming help mitigate further violence. Well-known and trusted strategies to rebuild social capital include supporting and rebuilding local institutions; fostering community-level reconciliation and the establishment of institutional mechanisms for conflict resolution, in addition to the disarmament, demobilization, de-radicalization and reintegration of ex-insurgents.

Investments in both local government capacity and community voice in the Lake Chad region hold great potential to improve the quality and inclusiveness of service delivery, as well as government legitimacy. Strengthening state authority and institutional capacity, with adequate financial and human resources, to enhance the scope and improving the quality of social service delivery at the local level is a key element of restoring the social contract.[183] Restoring state presence also implies responding to the root causes of the insurgency—such as through the provision of quality services in areas where there were no public services before—as well as taking advantage of new opportunities, such as formalizing the new markets provided by new population concentrations. Real and perceived state neglect and grievances related to the exclusion of certain regions or groups from services and opportunities can be important drivers of conflict and violence.[184] In such contexts, how investments and services are delivered matters just as much as what is delivered. A key aspect to the sustainable repair of social division in Lake Chad is ensuring equity in the provision of public infrastructure and services and employment opportunities by balancing social diversity. Addressing existing imbalances in access (*distance*) to services, markets and economic opportunities across different socio-economic and demographic groups (*division*) can have significant implications on employment, poverty and welfare. Community-driven development mechanisms can also be a useful step toward repairing service delivery in remote, conflict-affected regions where the state is absent and/or lacks capacity.

179 UNHCR and World Bank (2016).
180 UNHCR and World Bank (2016).
181 Magrin and Perouse de Montclos (2018).
182 UNHCR and World Bank (2016).
183 UNHCR and World Bank (2016).
184 United Nations and World Bank (2018).

Institutions and social relations (including between the government and the governed) need to be rebuilt alongside physical infrastructure, with the engagement of local communities. Greater engagement of citizens in planning, budgeting and service delivery can help promote accountability and transparency. Ensuring that historically marginalized groups are represented in discussions on local development decisions would help address existing divisions, instead of entrenching them. Local governments have a crucial role to play. Central governments can help create conditions for effective local governance, including through the transfer of responsibilities and *regular* financial resources to local governments, and through a more efficient distribution of roles between local government and government agencies.[185] The consolidation of oversight and check-and-balance mechanisms, at both central and local levels, can help reduce corruption and improve the quality of public services. More transparent and more legitimate local governments can also be more accountable for their budgets and activities.[186]

Public investment in core infrastructure and basic public services can be an engine for inclusive growth. Evidence from this report shows that access to electricity in the Lake Chad region is lower than in the rest of the respective countries, and the gap is widening both for access to improved sanitation and electricity. The lack of quality infrastructure and basic public services makes the Lake Chad region less competitive and an unattractive destination for firm entry and job seekers. The low level of service provision is further compounded by the conflict, which has driven people away from the region. Investing in core services and infrastructure—including, but not limited to, roads, water and sanitation services, and digital technology—is critical to unleashing the agglomeration potential of the region.[187] Public investments can improve the rural and urban water supply and sanitation, as well rural electrification, taking advantage of solar energy where possible.[188] Other priority activities include education adapted to mobile populations and health initiatives, such as local health stations; construction of regional hospitals, epidemics prevention, and family planning support.[189]

Improved governance and transparency can contribute to garner local resources toward public investment. The decline in oil revenues in addition to the negative impact from the violent conflict and climate change have weakened resources in the region, already experiencing weak fiscal management. In addition to support from the international community, local resources can contribute to the sustainability of recovery efforts. Strengthened governance and the provision of services can improve government legitimacy, encouraging citizens to support local development through cofinancing and the joint management of local investments and the payment of local taxes.

Enhancing fiscal space can help support social protection efforts. Social protection is important to addressing the need of inhabitants living in poverty. In parallel to creating fiscal space to support social safety nets (see Box 1.3), priorities for social protection include establishing a fiscally sustainable social assistance system and leveraging existing partner-financed programs. This could be achieved through better channeling fiscal revenues; strengthening coordination and alignment across the regional, federal, state, and local levels (for example, by leveraging data collection efforts, including registry databases); building local capacity for program delivery; and developing a common delivery platform for programs implemented by different ministries and agencies and at different levels of government. Well-designed targeted safety net programs could address the specific vulnerabilities of excluded groups, such

185 Magrin and Perouse de Montclos (2018).
186 Magrin and Perouse de Montclos (2018).
187 World Bank (2003).
188 LCBC (2015).
189 LCBC (2015).

as adolescent girls out of school, youth, and newly poor affected by violent conflict and climate change. In the context of the Lake Chad region, improving the performance of social assistance programs would require specific design and implementation efforts to gather and use credible, up-to-date, and relevant information to deliver well-targeted benefits, as well as to link cash-transfer and youth employment programs with other programs for nutrition, education and life skills, and health services, including at the community level. Complementarity between health and education services and social protection can enhance the impact of interventions. For example, health care, education, and social protection services that are effectively combined can serve as a stepping stone for rapid and successful urbanization.[190]

Subnational governments are responsible for delivering basic services; yet, they are highly dependent on fiscal transfers from the national governments to finance these services. Box 1.3 shows the case of Nigeria. At the national level, Nigeria, like the other three countries of the Lake Chad region, struggles to mobilize domestic revenues. As a result, there are limited resources to transfer to subnational governments. Moreover, because Nigeria depends on volatile oil revenues, fiscal transfers to local governments tend to be not only low but also unstable, to the detriment of basic services. Mobilizing domestic revenues and advancing fiscal decentralization, underpinned by enhanced public financial management, is thus a critical priority for national and subnational governments in the region.

Investing in data collection and analysis is a recommendation that cuts across all policy areas. This report highlights the value of data and analysis to inform policy making and development programming, especially disaggregated data that highlight differences across groups and territories and that help identify patterns of social marginalization and exclusion. The challenges and opportunities of the Lake Chad region remain inadequately studied and are most often looked at through a national lens, whereas effective and durable solutions tend to be regional and spatial. Data collection and analysis are insufficiently harmonized and coordinated, and subnational data on key socioeconomic and governance aspects are often lacking. Backing existing regional initiatives that support better access and quality of development data, local research capacity, and regional policy dialogue would promote evidence-based policy making.

Given the shared and interlinked challenges and opportunities across boundaries in the region, coordinated approaches and regional bodies can enable the emergence of a common vision for the development and stability of Lake Chad. Shared strategies, with equitable cost-sharing, hold great potential to address the interlinked security, economic and climatic challenges in the lake basin. Under the supervision of the African Union (AU), two regional consortia have been tasked with counterinsurgency and regional development, and made mutually accountable. On the security side, the Multinational Joint Task Force was authorized by the African Union to combat Boko Haram in 2014, under the civilian oversight of the Lake Chad Basin Commission (LCBC) (see Box 1.3).[191] On the development side, the LCBC was initially formed in 1964 to oversee and coordinate national decisions affecting the shared transboundary water resources—the lake, its tributaries and groundwaters. It was later tasked with security oversight, hence its supervision of the Multinational Joint Task Force today. Given the region's tense political economy and history of fractious inter-state relations, translating the aims of these two regional institutions into reality is a work in progress. Coordinated and jointly executed action—for example, border cooperation—remains one of the main cornerstones for stabilization and economic recovery.

190 World Bank (2009).

191 Eight member states are represented in the LCBC: Algeria, Cameroon, the Central African Republic, Chad, Libya, Niger, Nigeria, and Sudan. Parties commit to a shared use of the basin's natural resources.

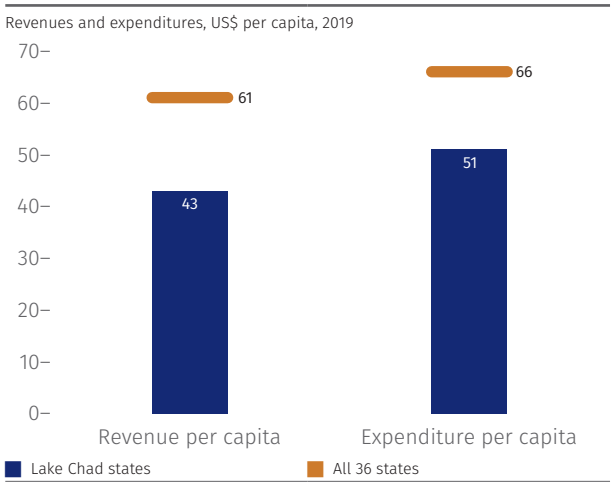
Box 1.3: The importance of fiscal transfers for subnational governments in the Lake Chad region: the case of Nigeria

State governments in Nigeria are responsible for basic service delivery. Together with their respective local governments (774 in total), the 36 Nigerian state governments are responsible for basic education, as well as adult and vocational education, health services, agricultural development, and basic physical infrastructure (sanitation, roads, and other public facilities).

The majority of revenues received by the Nigerian state governments (about 70 percent in 2018–2019) come from federally collected oil and nonoil revenues, distributed based on a formula. These revenues originate from customs, corporate taxes, and value-added taxes. They are distributed based on a revenue-sharing formula across the three tiers of government (federal, state, and local). These 'gross statutory allocations' are often volatile due the dependence on oil-revenues, which are sensitive to global price fluctuations. States can collect internally generated revenues, which include personal income, property, and road taxes, as well as other fees and levies. These internally generated revenues contribute, on average, about 30 percent of states' government revenue envelope. States can also borrow, including externally, with a federal government guarantee.

Adamawa, Borno, and Yobe—the three Nigerian states in the Lake Chad region—have below-average total revenues per person, depending thus heavily on revenue transfers from the federal government. These three states collect less than half the national average in independently generated revenues per capita. As a result, they are more dependent on federal revenue transfers than the national average. Borno, for example, relies on federal transfers for more than 80 percent of its revenues. The total annual revenue per capita is equivalent to US$34 in Borno, US$43 in Adamawa, and US$52 in Yobe. These figures are between 16–45 percent below the Nigerian state average of about US$60. Consequently, Yobe, Adamawa, and Borno have below-average public spending per capita despite the high development needs and security issues in these states. A weighted average nondebt public spending per person across Nigerian state government (excluding local governments due to lack of data) is US$66 per year (2019). In contrast, per capita spending in Adamawa (US$49) and Borno (US$40) is well below the national average. The budgetary state spending in Yobe, at US$64 per person per year, comes just below the national average.

Figure B1.3.1: Nigerian states in the Lake Chad region have lower revenues and expenditures per person than the average Nigeria state



Source: World Bank calculations based on data from Nigerian authorities.

Insecurity in the Lake Chad states in Nigeria is potentially influencing the composition of state public spending. Yobe, Adamawa and Borno allocated relatively more budgetary resources to recurrent spending components. Although the three states allocated a relatively higher proportion of their scarce budget resources to education and health in 2021 than the average state in Nigeria, they also allocated below average resources for expenditures

***Box 1.3** continued*

in the economic affairs segment (which includes agriculture, transport, and other core physical development components), which may undermine their long term economic growth prospects.

All Lake Chad states are making efforts to improve their fiscal sustainability. Notably, they are participating in the Federal Government's States Fiscal Transparency, Accountability, and Sustainability Program for Results, which is supported by the World Bank. This program rewards (through grants) substantive improvements in states' fiscal and financial management, including revenue and debt management, procurement, and citizen engagement. In fact, Yobe is the top performer across all 36 participating states in Nigeria since the inception of the program, achieving the highest results. All three Lake Chad states also achieved the new COVID-responsive results introduced in 2020 to help marshal fiscal resources to the states amidst the pandemic.

1.6.4 Natural Resource Management

Strengthening the sustainability of food systems is a priority. Interventions at the regional level can help strengthen the capacity of food systems to ensure food security. Three areas of focus, identified by a World Bank and FAO report on West Africa, refer to strengthening the sustainability of the food system's productive base; promoting an enabling environment for intraregional value chain development and trade facilitation; and enhancing regional risk management architecture and farmer decision support tools.[192] On this last element, risk management tools—such as improved information and crop and rainfall insurance—can help people mitigate risks.[193] This ability, in turn, can allow people, particularly the poor, to be more willing to take on risk in search of higher yields and productivity. At the same time, social protection programs and safety nets can help reduce target populations' vulnerability in hotspot areas. Notwithstanding the importance of these tools, the implementation of these interventions in the Lake Chad region needs to be evaluated in the context of limited fiscal space and considering the time dimension, as well as—in the case of safety net programs—their potential implications and interactions relative to the armed conflict.

Expanding support for producers—in the forms of credit, inputs, extension services as well as investment in infrastructure—is essential to the productivity and resilience of food production systems.[194] In addition, securing the access of vulnerable populations to land, pasture, and fishing resources (in an inclusive way, promoting coexistence with other producers in the area) can prevent conflict and enable intensification. At the same time, initiatives to support agricultural production may benefit from explicitly recognizing the coexistence of different—and, at times, competing production models—such as those of farmers and herders. Agriculture is not a homogeneous sector, and understanding the potential tensions between modes of production can shed light on a core issue of conflict dynamics.

Securing land rights in the Lake Chad region may help enhance productivity as well as stability in the region. The formalization of land rights has the potential to improve agricultural productivity by incentivizing farmers to make long term investments.[195] Formalizing land ownership may also help reduce friction and conflict between farmers, pastoralists and fishers vying for limited access to land and water resources in and around the lake basin. This can be particularly important in a context where increasingly erratic climate has introduced a greater

192 World Bank and FAO (2021).
193 World Bank (2013b).
194 LCBC (2015).
195 World Bank and FAO (2021).

degree of uncertainty to the availability of such land and water resources.[196]

There are substantial expected gains from context-specific natural resource management interventions that take into account the specific circumstances of a given population or territory. A key aspect of these interventions is taking into account the cases for which place-based policies—i.e. territorial development—are likely to have a positive outcome, and in which cases people-based policies—more focused on efforts in urban areas to better absorb migrants—can be a better alternative. In the case of the latter, coordinated efforts to strengthen services and employment opportunities in urban areas can help ensure that poverty is not merely being displaced from rural to urban areas. In the case of the former, efforts to support producers, including vulnerable groups, considering local tensions and dynamics can bring about sustainable productivity improvements, as mentioned above. Context-specific discussions are thus essential to inform effective natural resource management.

Investing in sustainable agricultural management through technological innovations can help increase output and harness existing natural resources. Technology and innovation can reduce climate uncertainty among farmers and enable better decision-making, increase yields and reduce waste.[197] The optimal use of natural resources driven by technology can be key in reducing environmental degradation and mitigating risks stemming from volatile temperature and water levels. The support from governments in the Lake Chad region to facilitate this transfer of technology, in tangent with the international community, can help enable vulnerable populations to benefit from access to technology. Efforts could include bringing together agricultural research centers and setting up an optimal matching mechanism between farmers and agricultural inputs adapted to their climatic and social context.[198] Setting up a knowledge dissemination campaign in local languages can raise awareness among local producers of the potential climatic risks and novel agricultural inputs and techniques available.[199]

Preventive rather than reactionary policies can more successfully mitigate risks stemming from climate change and build local adaptive capacity. Shifting from ex-post responses to proactive, ex-ante, sustained, and integrated risk management is no easy feat. Yet, it is well documented that the benefits of proactive actions far outweigh the cost of "risk inaction." Facilitating an environment for coordinated action and risk-sharing in the region can enable this process while ensuring that vulnerable stakeholders are not overlooked. Knowledge sharing and dissemination can help reduce the uncertainties faced by people living near Lake Chad, for example, by setting up a regional early warning system to better cope with natural disasters, such as floods and droughts.[200] Overreliance in reactionary policies discourages investments in adaptive capacity across poorer households, making them more vulnerable to future climate-related shocks, perpetuating the current conflict-poverty trap.

Water stress and climate vulnerability validate the continued engagement of the LCBC on shared water management, while enhanced participation may be needed. Development partners can invest strategically and ensure a higher standard of donor coordination and harmonization at the regional and basin level, particularly as climate finance increasingly comes into play (Box 1.4). Member states actively promote and seek funding for regional infrastructure for an interbasin transfer, yet lag on the more basic levels of regional cooperation. External

196 See more discussion on the linkage between land rights (or lack thereof) and conflict in the Lake Chad Basin: https://climate-diplomacy.org/case-studies/local-conflicts-over-resources-around-lake-chad.

197 World Bank (2019b).

198 LCBC (2020).

199 LCBC (2020).

200 LCBC (2020).

support needs to follow the logic of domestic incentives, and design aid so that it promotes—when possible—long-term development and conservation focusing on the southern tributaries of the lake. Examples from other regions suggest that technical cooperation can, in the long run, incentivize member states to take water cooperation more seriously.

Strengthening the administrative and institutional capacity of the LCBC could help the organization more effectively manage water resources and climate-response policies. An insufficient clarity of roles and competencies, as well as a lack of investment and interest by member states, emerge as some of the current institutional constraints faced by the commission and the Multinational Joint Task Force (see Box 1.4).[201] Enhancing the operational capacity of the LCBC could include regular meetings, data- and information-sharing, and sustainable financing. Establishing viable systems for information and data collection and exchange may pave the way for gradual buy-in and trust-building in the future. Reliable data and hydrological modeling are an urgent concern, especially as plans for major infrastructure works, including those for an interbasin transfer remain on the agenda. National statistical offices could facilitate the standardization of agricultural data collection and set up a readably available database that feeds into early warning forecasting models.

The Lake Chad region has vast development potential; unlocking this potential will foster the creation of greater opportunities for its citizens. The region has a young population, is rich in natural resources, and in the past has seen important trade flows. Yet, it is also a region facing long-term and pressing challenges, particularly a self-reinforcing vicious cycle between suboptimal territorial development and FCV. Throughout discussions with stakeholders in the region, there was broad consensus on the need to break the cycle. Doing so will require sustained implementation of a holistic agenda and thus broad societal consensus and a long-term political commitment at the highest level. The priorities identified in this Regional Economic Memorandum seek to help guide policy for breaking this cycle and bridging the gap between potentials and actuals.

201 Assanvo, Abatan, and Sawadogo (2016); Galeazzi et al. (2017).

Box 1.4: Transboundary water management in Lake Chad

Transboundary water management may serve to consolidate regional interests and prevent resource-related tensions from turning violent. In the Lake Chad region, effective water management of the lake and its tributaries can help foster greater coordination among the four basin countries.

While the Lake Chad Basin Commission (LCBC) has thus far prevented nonconsensual action by a member state, such as upriver damming, it scores relatively low among other African transboundary water agreements. The efficacy score is based on the degree of transboundary cooperation, or water cooperation quotient, an indicator combining criteria, such as the existence of river basin agreements, a river basin authority, current and planned investment in water infrastructure, political commitment, economic cooperation, and so forth.[a] As assessed by the Strategic Foresight Group (2017), Senegal, the Gambia, and the Niger river basins ranked highest, meeting 100 percent of the criteria, among 231 transboundary watercourses. In contrast, the LCBC scored 53 percent.

The LCBC was initially formed in 1964 to oversee and coordinate national decisions affecting the shared transboundary water resources, including the lake, its tributaries, and groundwaters. Eight member states are represented in the LCBC: Algeria, Cameroon, the Central African Republic, Chad, Libya, Niger, Nigeria, and Sudan. Parties commit to shared use of the basin's natural resources. The multidonor joint fund, the Sahel Alliance, has undertaken an economic recovery program covering conflict-affected regions of the Lake Chad Basin, though most of its investments are concentrated in the Western Sahel.

The Lake Chad Basin Authority's charter was developed in 2012 to foster the shared management and sustainable exploitation of Lake Chad. As with other progressive water agreements and regional charters, it has not yet entered into force. In 2015, faced with increasing and new forms of insecurity and the absence of a dedicated regional bloc, the LCBC's mandate increased to include oversight of regional security cooperation through the task force. Yet, in its transboundary water management capacity, LCBC's leverage over member state interests to deliver coordinated water management is limited.

The performance of LCBC is mixed not least because mechanisms and tools to monitor and control the use of water resources are not fully operational. This partly derives from the insufficient clarity of roles and competencies, but also from an apparent lack of political interest and investment among member states. The main players, including Nigeria, have invested some political capital in the organization, but tend to favor more politically visible interventions. For example, the massive proposed transnational inter-basin investment to transfer water from the Congo River Basin to Lake Chad is favored over structural interventions to address the environmental decline and agricultural transformation in the wider basin area, particularly around the southern tributaries of the lake. While technically feasible, the massive infrastructure project is estimated to have an extremely high cost. It has been criticized for potential adverse effects on the ecosystems of both basins as well as possible negative effects on the flow of the Congo basin. The World Bank, the United Nations Educational, Scientific, and Cultural Organization, and other major donors do not endorse the large-scale hydro infrastructure as a Lake Chad basin management solution. These entities have funded multiple studies and proposals for the collective management of the lake resources through the Lake Chad Development and Climate Resilience Action Plan, which funded €6 million worth of feasibility studies for the inter-basin water transfer proposal. UNESCO sponsored the International Lake Chad Conference in 2018 in which LCBC countries endorsed an Italian proposal, Transaqua, as their preferred option for the inter-basin water transfer project.[b]

a. Strategic Foresight Group (2017).
b. See PAMACC (2018); Sayan, Nagabhatla, and Ekwuribe (2020).

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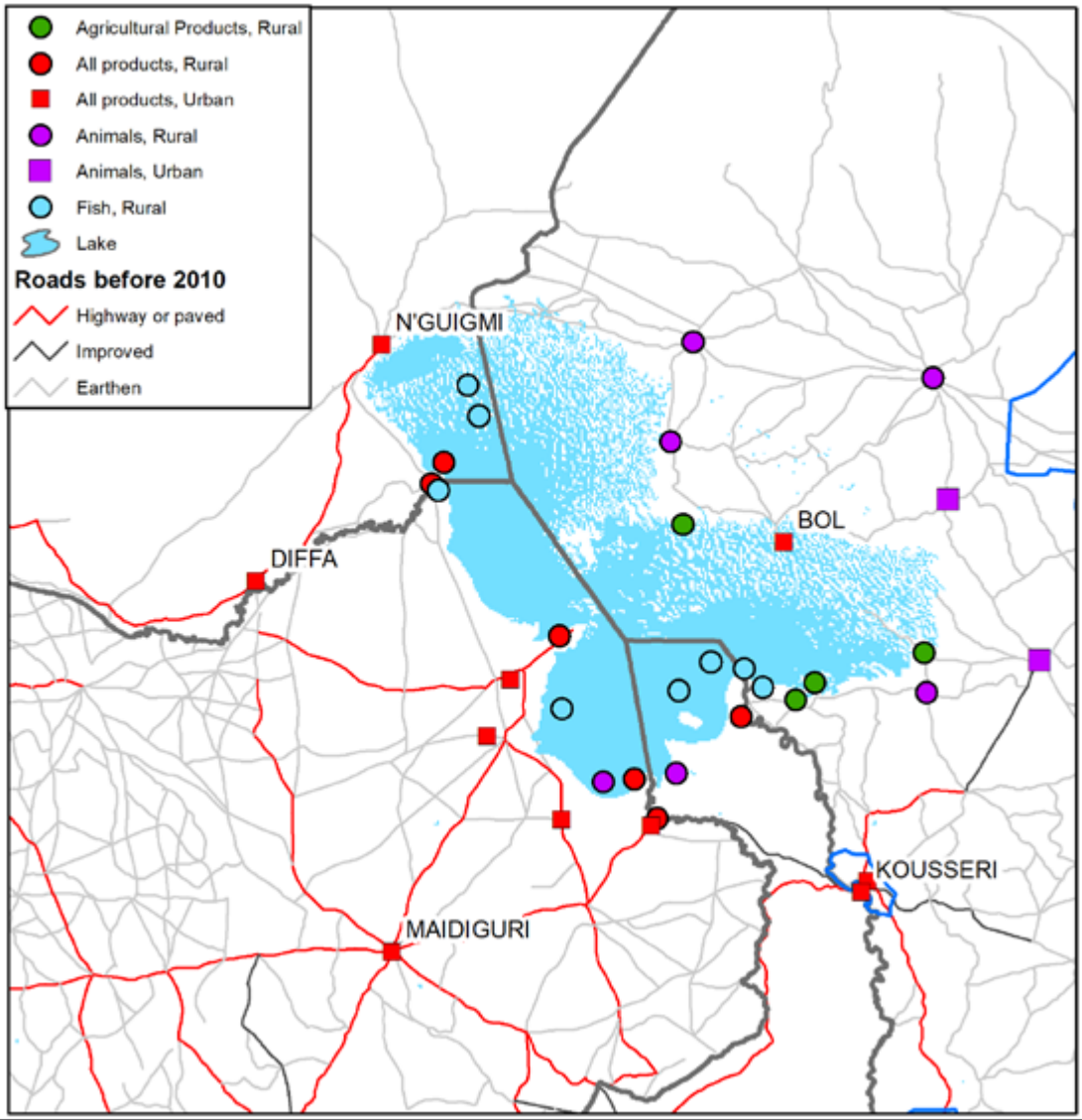
Appendix 1.A: Supplementary Figures and Tables

Figure A1.1: Local markets in proximity to Lake Chad by type



Source: Blankespoor 2021, technical paper for this report.

Table A1.1: Socioeconomic Outcomes in the Lake Chad Region and Other Regions

	Cameroon			Chad			Niger			Nigeria		
	National	*Rest of country*	*Lake Chad region*	*National*	*Rest of country*	*Lake Chad region*	*National*	*Rest of country*	*Lake Chad region*	*National*	*Rest of country*	*Lake Chad region*
Poverty and Human Capital (percent)												
Poverty	26.0	18.8	58.8	38.1	39.8	30.7	45.4	43.4	51.6	39.1	37.7	72.3
Literacy (15+)	77.8	83.7	47.1	41.6	45.5	21.0	33.0	32.8	34.0	71.9	72.4	58.7
Primary Completion (14–25)	72.3	79.0	39.4	29.5	32.8	12.2	25.4	27.8	17.4	78.2	79.0	60.0
Child stunting	28.9	26.9	37.3	39.9	37.0	51.0	43.9	41.7	52.2	36.8	35.8	48.0
Employment (percent)												
Agriculture	45.9	39.0	78.0	76.2	77.0	72.2	74.7	75.5	68.5	43.2	42.2	43.2
Industry	15.6	17.1	8.7	7.0	6.9	10.2	7.9	7.2	7.5	9.4	9.5	9.4
Service	31.0	35.3	10.9	13.6	12.8	17.0	15.6	15.2	20.4	37.1	37.7	37.1
Access to Public Services (percent)												
Piped Water	35.6	39.6	14.8	15.9	16.4	13.8	31.8	34.7	23.5	11.2	10.4	20.7
Improved Sanitation	61.1	66.9	30.8	14.1	16.2	5.7	24.8	28.5	14.3	56.3	56.4	55.1
Electricity	62.2	70.4	19.6	7.7	9.0	2.4	14.4	16.0	10.0	59.4	61.3	38.4

Source: World Bank calculations based on data of the national authorities.
Note: Data on education (literacy and primary education), and employment are based on the latest household surveys conducted in Cameroon (2014), Chad (2018), Niger (2018), and Nigeria (2018). Job category by industry includes only working-age individuals (ages 15–65). Data on poverty are based on the latest harmonized household surveys conducted in Cameroon (2014), Chad (2011), Niger (2014), and Nigeria (2018). Poverty rates are based on the US$1.90 international poverty line (2011 purchasing power parity). Data on child health (child stunting) and access to public services are drawn from the latest Demographic and Health Surveys available in each country: Cameroon (2018), Chad (2018), Niger (2012), and Nigeria (2018). Rest of country = outside the Lake Chad region; LCB = within the Lake Chad Basin region.

Appendix 1.B: Infrastructure Investment Scenarios Explored in the Technical Paper "Infrastructure and Structural Change in the Lake Chad Region"

New transport infrastructure in the Lake Chad region

New rail line in Cameroon: The renovation of the rail line between Ngaoundéré, Yaoundé and Douala in Cameroon is going through several steps. The World Bank participates in the financing of the southern part of the project for the segment between Douala and Yaoundé, while the EU and European Investment Bank finance the northern part. We assume that the two rehabilitations will happen at the same time; so we consider the whole segment. The government is currently planning to renovate the most used segment between Yaoundé and Douala, the condition of which has deteriorated in the last years. The northern segment between Ngaoundéré and Yaoundé is the most deteriorated. We assume the speed is low on the whole line in the baseline.

New road corridors in Chad: There are several historical corridors between Cameroon and Chad. Tensions in the Far North Region have closed the corridors passing by the Northern part of Cameroon and opened the possibilities for other corridors to develop. The World Bank is currently assessing the possibility to invest in a new corridor in Chad. The proposed corridor links the capital of Chad with Moudoun, the second most important city in Chad, which increases the relevance of the project as it increases domestic connectivity between the main two cities and the regional/international connectivity of Moudoun.

Complementary policies: Border frictions We assume that trade across locations from a same country only face transport costs while traders across countries have to wait an additional 30 hours to be able to cross the borders. Give the lack of data, we assume a level of 30 hours by default. In the forthcoming counterfactuals, we add a reduction of half border time to the transport investments.

Appendix 1.C: List of Technical Papers

Seven original technical papers were produced to inform the preparation of this report.

Title: **"Socioeconomic Trends in the Lake Chad Region"**
Authors: Takaaki Masaki (World Bank) and Carlos Rodríguez-Castelán (World Bank)
Abstract: This paper offers a descriptive snapshot of recent socioeconomic trends in the Lake Chad region. It finds that areas around the lake exhibit significantly higher poverty rates compared with other parts of the corresponding countries. The region presents chronic human capital deficits, a historical lack of access to basic services and infrastructure, and—particularly since the onset of the crisis—limited access to large markets. The study also highlights how the level of economic density is especially low in the Lake Chad region relative to other areas, while a chronic lack of connective infrastructure (large distance) and perpetuation of conflict (wide divisions) may delay regional economic progress.

Title: **"Climate Change, Rural Livelihoods, and Urbanization: Evidence from the Permanent Shrinking of Lake Chad"**
Authors: Remi Jedwab (George Washington University), Federico Haslop (George Washington University), Takaaki Masaki (World Bank), and Carlos Rodríguez-Castelán (World Bank)
Abstract: Many of the world's lakes are disappearing. Despite an extensive literature on the economic consequences of climate change, the economic effects of diminishing lakes have not been widely investigated. We focus on Lake Chad, a vast African lake that lost about 90 percent of its surface area between 1965 and 1985. For Cameroon, Chad, and Niger, we construct a novel dataset tracking total and urban population patterns at a fine spatial level from the 1950s to the 2010s. We then exploit a difference in differences strategy to estimate the causal effects of the shrinking of Lake Chad between the 1960s and the 1990s on nearby communities. We find relatively slower total population growth in the proximity of the lake, but only after the lake started shrinking. We also find nonnegative effects of the lake shrinking on city population growth nearby, which suggests that climate change might induce refugee urbanization locally.

Title: **"Estimating the Spillover Economic Effects of Foreign Conflict: Evidence from Boko Haram"**
Authors: Remi Jedwab (George Washington University), Brian Blankespoor (World Bank), Takaaki Masaki (World Bank), and Carlos Rodríguez-Castelán (World Bank)
Abstract: What are the spillover effects of foreign terrorism and conflict on regional economies? Adopting a difference in differences framework to leverage the unexpected rise of the Boko Haram insurgency in Nigeria's North East in 2009, we study its effects in neighboring areas in Cameroon, Chad, and Niger. We find strong negative effects on regional economic activities (proxied by reductions in nighttime lights), particularly among areas within 200 kilometers of the Boko Haram area. Our findings suggest that this negative impact is concentrated in urban areas and is pronounced among those areas that were initially less developed, for example, in infrastructure, and less well connected to other markets (indicating a lack of trade diversification). We also find that the rise of Boko Haram results in more agricultural burning, a local agricultural practice that is profitable in the short term, but typically leads to long-term environmental and economic losses. Overall, these findings attest to both the short-term and long-term negative impacts of foreign conflicts on regional economies.

Title: **"Infrastructure and Structural Change in the Lake Chad Region"**
Authors: Mathilde Lebrand (World Bank)
Abstract: Access to infrastructure supports economic development through structural transformation. Roads provide access to markets, while electricity and internet allow for modern production technologies. This paper investigates the links between investments in electricity, internet, and road infrastructure, in isolation and bundled, and economic development in the Lake Chad region. Using data on the expansion of the road, electricity, and internet networks, we provide reduced-form estimates of the impacts of infrastructure investments on the sectoral composition of employment. Using a series of instruments, we estimate a large impact of infrastructure investments, especially from the combination of paved roads and electricity. We then use a spatial general equilibrium model, based on Moneke (2020), to quantify the impacts of future regional transport investments and trade facilitation on economic development. Better regional transport connectivity along the Douala-N'Djamena corridor will bring relatively large welfare gains for the Lake Chad area and lead to increased specialization in manufacturing in southern Cameroon and in agriculture or nontradable services elsewhere.

Title: **"Conflict and Climate in the Lake Chad Region"**
Authors: Peter Fisker (University of Copenhagen)
Abstract: This paper investigates determinants of conflict across districts and grid cells in the Lake Chad region, which covers parts of Cameroon, Chad, Niger, and Nigeria. Information on conflict incidence and intensity is combined with remote sensing data on greenness, temperatures, rainfall, and the standardized precipitation-evapotranspiration index (SPEI) in all years between 2001 and 2018. The results indicate that conflict in the Lake Chad region is affected by climate anomalies: higher-than-usual temperatures lead to an increase in conflict activity measured at the district and grid cell levels. Greenness anomalies also affect conflict negatively, but more strongly if one focuses on the growing season in cropland areas. However, rainfall and the SPEI do not exhibit similar relationships with conflict. Possible reasons for this may be that (a) temperature anomalies are more important than agricultural drought as predictors of conflict or (b) measurement errors in the rainfall and SPEI data under analysis.

Title: **"Building Rural Development in the Lake Chad Region"**
Authors: Brian Blankespoor (World Bank)
Abstract: Agriculture is the main sector of economic activity among individuals and households in the Lake Chad region. However, limited market accessibility and, more recently, conflict hinder agricultural activity and therefore pose major challenges to the economic recovery and development of the region. This paper uses panel methods to examine the relationship between access to markets and land cultivation in the region over the past three decades using recent satellite and spatial data following the framework of Berg, Blankespoor, and Selod (2018). The results provide evidence that an increase in market access is associated with an increase in cultivated land and is positively associated with an increase in local agricultural gross domestic product (GDP). Even so, conflict because of the rise of Boko Haram in the past decade may attenuate gains because the proximity to conflict events in the previous year is associated with less cropland across the entire region and less nighttime lights for a panel of 104 local markets near Lake Chad.

Title: **"Trade Patterns and Trade Networks in the Lake Chad Region"**
Authors: Peter Walkenhorst (American University of Paris)
Abstract: This paper synthesizes existing evidence on trade patterns and trade networks in the Lake Chad region and on the significant disruptions encountered by trade flows in the region. It argues that conflict and the corresponding mitigation measures have affected trade flows in multiple ways. First, they affect important local production and markets, such as lake and river fish (Maiduguri is a hub of the trade), and food staples, such as sesame, onion, and

pepper. Second, they also impact significant trade flows passing through the region. From the north to the south, the cattle trade that historically passed through the region on both the northern and southern shore of the lake now heads eastward toward Central Africa instead. From the south to the north, important transit trade, such as along the Douala-N'Djamena corridor, is now diverted through Moundou. Third, they affect trade with the two large economies, Cameroon and Nigeria, which has relocated from the conflict-ridden northern regions to safer border areas.

Part II: Technical Papers

Technical Paper 1. Socioeconomic Trends in the Lake Chad Region

Takaaki Masaki (World Bank) and Carlos Rodríguez-Castelán (World Bank)

2.1 Introduction

The Lake Chad region—which is an economically- and socially-integrated area spanning across four countries of Chad, Cameroon, Niger, and Nigeria in north-west Africa—has been trapped in a vicious circle of suboptimal territorial development and fragility. People in the region are confronted with multidimensional development challenges ranging from limited economic opportunities, poor governance, lack of basic access to services, among others. These challenges also have fueled violence and conflicts in the region. Ten years of conflict, mainly driven by the Boko Haram insurgency, have left an estimated 12.8 million people in need of humanitarian assistance in the Lake Chad region, 2.7 million of whom are people displaced by the conflict.[202]

Despite the salience of the Lake Chad region as a hub for regional stability and growth, there is a lack of data and evidence on the socio-economic landscape of the region. Identifying opportunities for inclusive growth in the region entails understanding its current status in terms of its economic activities/trends, access to services, FCV (fragility, conflict, and violence) challenges and human development as well as its status vis-à-vis other areas of the countries.

The main objective of this note is to fill in the knowledge gap on the socio-economic trends of the Lake Chad region by providing a descriptive snapshot of economic activities, poverty, and human development in the Lake Chad region. The main questions that this note seeks to answer are: (i) what are the current levels of economic activity and social inclusion in the region compared with other regions in the bordering countries?; (ii) how do these socio-economic outcomes change within the region and over time?; and iii) what are the main correlates of the long-term transformation of the region?

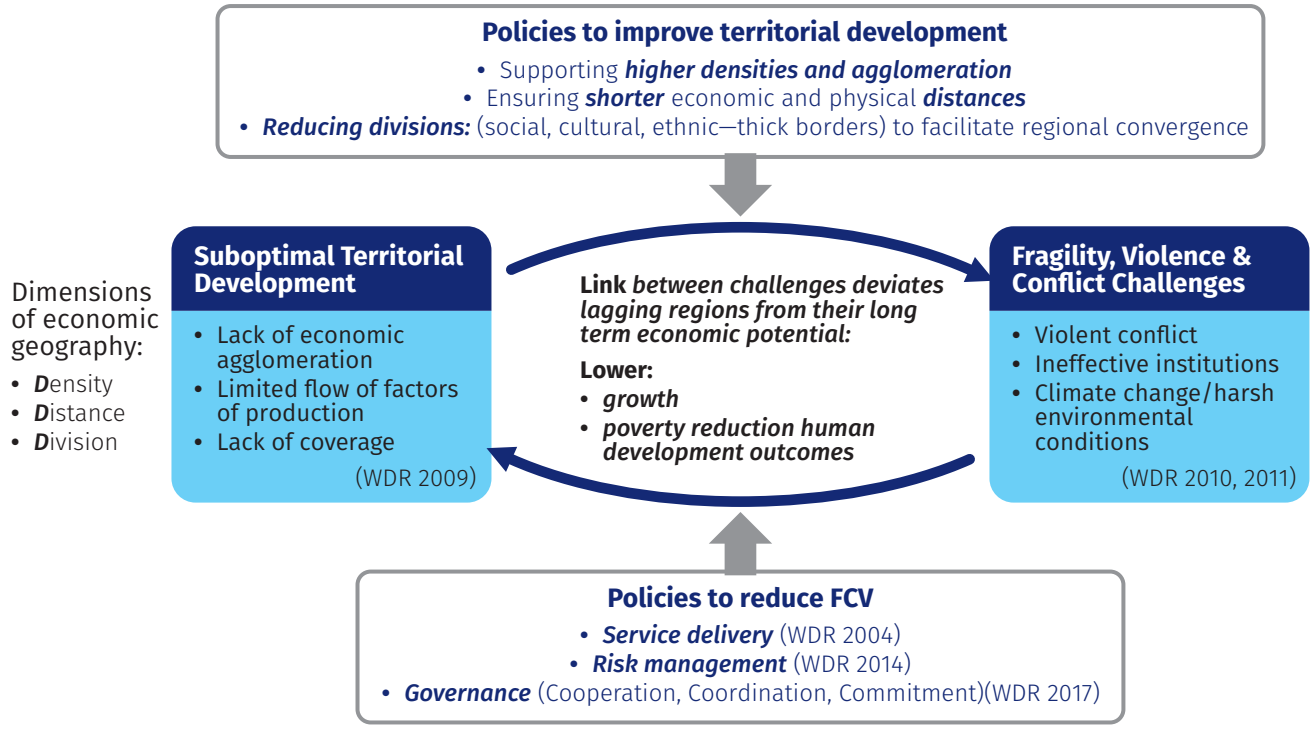
To answer these questions, we draw on the analytical framework developed in WDR2009 which focuses on three dimensions of economic geography—namely, density, distance and division. First, *density* refers to the economic mass per unit of land area, or the geographic compactness of economic activity. It is shorthand for the level of output produced—and thus the income generated—per unit of land area. It can, for example, be measured as the value added or gross domestic product (GDP) generated per square kilometer of land. Second, *distance* refers to the ease or difficulty for goods, services, labor, capital, information, and ideas to traverse space. It measures how easily capital flows, labor moves, goods are transported, and services are delivered between two locations. Distance, in this sense, is an economic concept, not just a physical one. Lastly, *division*, by contrast, refers to any restrictions on the mobility of people, goods and services due to border restrictions, territorial disputes, civil wars, and conflicts between regions and countries, among others.

Figure 2.1 graphically shows how this territorial development perspective fits in the overall conceptual framework for the Lake Chad Regional Economic Memorandum.

This note shows that the Lake Chad region lags behind in multiple dimensions of development ranging from poverty, human capital, and access to services. A poverty rate in the Lake Chad region is found to be much higher than other parts of the countries surrounding the lake. The regional poverty rate in the Extreme North region of Cameroon (59 percent) is three times higher

202 Of the 12.8 million people in need of humanitarian assistance, 10.6 million are from northeastern Nigeria's three most-affected states: Adamawa, Borno, and Yobe (USAID, 2020).

Figure 2.1: Conceptual Framework Highlighting Opportunities to Strengthen Territorial Development and Addressing Fragility in the Lake Chad Region



Source: World Bank elaboration based on World Bank 2003, 2009, 2010, 2011, 2013b, 2017.

that of the rest of the country (19 percent). In Nigeria, the Lake Chad region[203] has a poverty rate (72 percent) nearly twice as high as in the rest of the country (38 percent). Chad is the only exception, where the poverty rate in the country's Lake Chad region (31 percent) is lower than the rest of the country (40 percent).[204] This is explained by the fact that the Chad region around the lake lies near the capital of the country, with a consequently higher urbanization rate and a relatively high population density.

There is little sign that the spatial gap between the Lake Chad and other parts of the countries is narrowing over time. In Cameroon, for instance, poverty declined by 4 percent in the Extreme-North region compared to a 6 percent decrease in the rest of the country between 2007 and 2014. While Niger as a whole saw a reduction in poverty from 51 percent to 45 percent between 2011 and 2014, its Lake Chad region experienced a slight increase in poverty from 48 percent to 52 percent. The analysis of nighttime light also shows no sign of convergence in the level of economic activities between the Lake Chad and rest of the countries. Overall, there is little indication that such spatial gaps in poverty and economic development are narrowing.

One of the key drivers for regional growth lies in improving connectivity to large markets. A large swath of rural areas in the Lake Chad region still have limited access to large markets and, as highlighted earlier, these areas are typically characterized by slower growth in economic activities. Our estimate suggests that about 60 percent of rural population in the Lake Chad region live farther than 2km away from all-season roads (proxied by *OpenStreetMap*), while this rate is much lower in

203 The country's Borno state is excluded from the analysis given that there is no representative household survey for that state.
204 Mahmood and Ani (2018).

other parts of the countries, at about 30 percent. Poor road infrastructure undermines intra- and inter-regional connectivity across the Lake Chad Region, thereby limiting economic opportunities for people in the region. On the other hand, areas proximate to population centers tend to have greater market accessibility due to a wider and dense road network system, which allows people living near the city to benefit from its agglomeration economies. Our analysis of nighttime light also reveals that areas with greater market access experience a faster local economic growth, attesting to the important role that road infrastructure and access to markets play in driving regional growth.

Larger urban agglomerations continue to expand their economies while leaving smaller ones behind. Our analysis shows that after accounting for various other geographic and socio-economic factors, larger urban agglomerations tend to grow faster economically than smaller ones. In fact, vibrant economic dynamics measured by changes in nighttime light luminosity are spatially concentrated in areas that are already highly populated initially while those sparsely populated areas have continued to see little economic progress over time. This attests to a potential widening gap in major cities vis-à-vis smaller periphery towns or rural areas.

Climate and conflict risks also play a role in determining the trajectory of regional growth. Our econometric findings reveal that agrarian areas that experienced favorable weather conditions experienced a faster rate of growth in economic activities compared to less favorable weather conditions. Given that climate change has made weather increasingly more erratic within the Lake Chad and also in the surrounding countries, the economic implications of such climate shocks need to be evaluated carefully depending on local contexts. Another significant economic threat comes from the highly volatile security situation created by the Boko Haram. The Boko Haram activities are also negatively associated with the pace of local economic growth and mitigating security risks should remain among the top priorities for ensuring the sustainable growth of the region.

The note is organized as follows. Section 2.2 provides key statistics on poverty, sector of work, and human capital indicators in the Lake Chad region vis-à-vis other parts of the country and examine how the Lake Chad lags behind in different dimensions. Section 2.3 provides a diagnostic of economic geography with a focus on three dimensions of density, distance and division. Section 2.4 identifies a set of structural factors, aggregate shocks and selected policies that might be associated with the dynamics of economic activity and social inclusion across the region.

2.2 Recent Socio-economic Trends in the Lake Chad

The Lake Chad region is an economically- and socially-integrated area in north-west Africa that has development potential. The Lake Chad region comprises a set of administrative areas across Cameroon, Chad, Niger, and Nigeria that surround the lake (Map 2.1). Throughout this note, the boundaries of the Lake Chad region are defined by ten different regions/states: the Chari Baguirmi, Kenam, Lac, and Hadjer Lamis regions in Chad; the Diffa and Zinder regions in Niger; the Far North region in Cameroon; and Borno, Adamawa, and Yobe states in Nigeria (Map 2.2).[205]

An estimated 30 million people live in the Lake Chad region[206] and they are primarily involved in agriculture and fishing activities. Agriculture and fishing generate significant indirect employment in related activities such as food processing, trade, transport, and production of crafts. These economic activities contribute to the food and job security of people in its hinterlands, including its two regional metropolises with seven-figure populations: N'Djaména, the Chadian capital, and Maiduguri, the capital of the Nigerian State of Borno.[207] Linkages with neighboring areas suggest that the livelihoods of as many

Map 2.1: Map of the Lake Chad

Source: Magrin, Lemoalle, Pourtier, 2015. *Atlas du lac Tchad.*

Source: World Bank's Lake Chad Region Recovery and Development Project (PROLAC).

Map 2.2: Administrative definition of the Lake Chad region

Source: Authors' elaboration. The shapefiles of the boundaries of the subnational areas are taken from GADM3.6.

205 The proposed administrative definition for the Lake Chad region is consistent with the one used in the World Bank's Lake Chad Region Recovery and Development Project (PROLAC).

206 Authors' calculations based on remote-sensing data from WorldPop (2020) (database) and using the proposed administrative definition of the Lake Chad region for this activity. The population estimate was calibrated using the latest census data available from: Thomas Brinkhoff: City Population, http://www.citypopulation.de.

207 See Magrin and Perouse (2018).

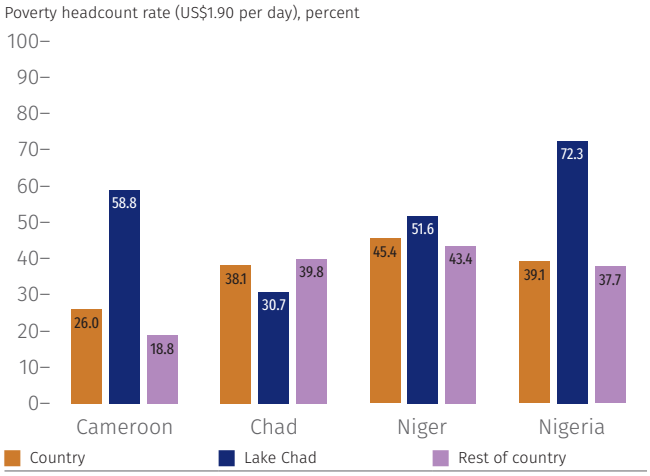
as 50 million people are linked to economic activities based on the Lake Chad region.[208]

The region's population is growing at a rapid pace. High fertility rates are the main factor explaining high population growth levels in Cameroon, Chad, Niger, and Nigeria. In the four countries, the population could double in the next 25 years. In the Lake Chad region itself fertility rates are very high, which means that the population could grow faster than other parts of the countries it belongs to. The population in the Lake Chad region increased by almost 4 million people between 2000 and 2015. The total fertility rate (TFR) in the region is higher in the administrative areas of Cameroon (estimated at 6.8 children per women) and Nigeria (5.8 children per women) compared to other parts of the countries (averaging 4.8 children per women in the rest of Cameroon, and 5.3 children per women in the rest of Nigeria). In Niger's Diffa and Zinder regions, fertility rates are also high at 8.2 children per woman (7.5 in other parts of the country). In the Lac and Hadjer Lamis regions in Chad, the average fertility rate is high at 6.2 children per woman, albeit slightly lower than the average of 6.5 children per woman in other parts of the country.

2.2.1 Trends in poverty reduction

Given its high poverty rate, low human capital and poor access to key services, the Lake Chad region is characterized as a lagging region. An analysis of the most recent household surveys available for each country shows that households in the Lake Chad region are poorer compared to households in neighboring regions (Figure 2.2). The regional poverty rate in the Extreme North region of Cameroon (59 percent) is three times higher that of the rest of the country (19 percent). In Nigeria, the Lake Chad region has a poverty rate (72 percent) nearly twice as high as in the rest of the country (38 percent). Chad is the only exception, where the poverty rate in the

Figure 2.2: Poverty is more severe in the Lake Chad basin vis-à-vis in the rest of the countries



Source: Data on poverty based on the latest household surveys conducted in Cameroon (2014), Chad (2011), Niger (2014) and Nigeria (2018).
Notes: Rest of country = outside the Lake Chad region; Lake Chad = within the Lake Chad Basin region.

country's Lake Chad region (31 percent) is lower than the rest of the country (40 percent). This is explained by the fact that the areas around the lake in Chad lie near the capital of the country, with a consequently higher urbanization rate and a relatively high population density.

There is also a significant spatial gap in poverty *within* the Lake Chad region. Poverty is most prevalent in the parts of the Lake Chad region that lie within the boundary of Nigeria. The poverty rates in Adamawa and Yobe States reach as high as 74 percent and 70 percent, which are significantly higher than the national average of 38 percent (Map 2.3, Panel B). These regions also are home to the largest number of the poor in the Lake Chad region (Map 2.3, Panel C). On the other hand, Kanem Region in Chad has the lowest poverty rate (of 19 percent) across the Lake Chad region.

Not only is the level of poverty relatively high in the Lake Chad region versus that in the rest of the countries but the pace of poverty reduction in the region is also slow. In fact, there is little sign that the spatial gap in poverty between the Lake Chad region and neighboring regions is narrowing over time. In

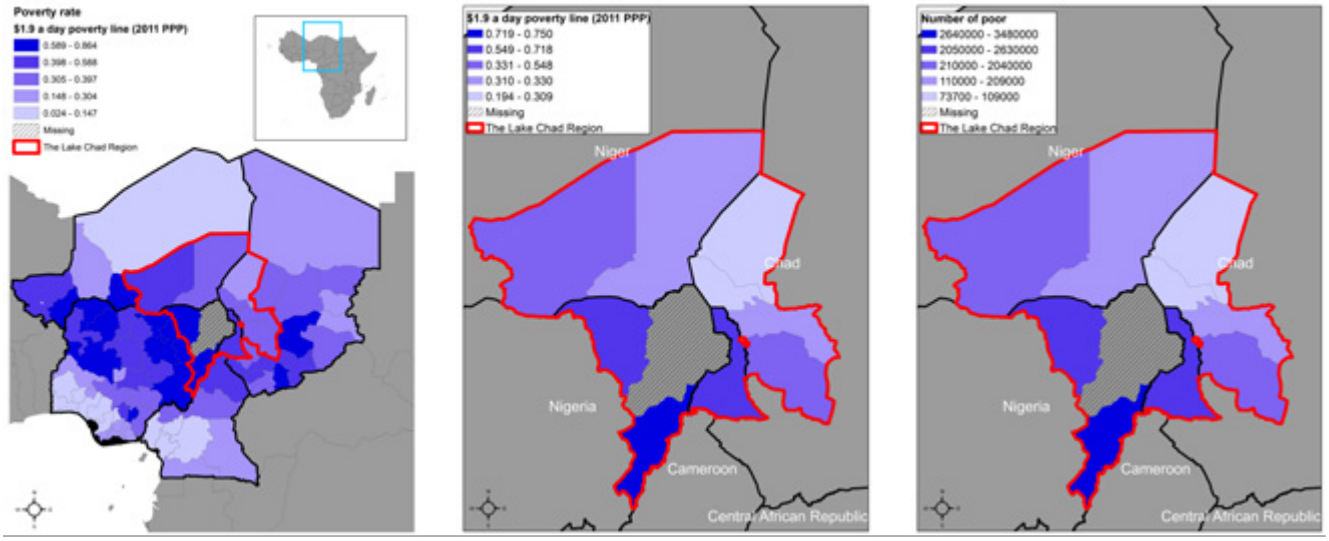
208 Adelphi (2019).

Map 2.3: Poverty in the Lake Chad region

a. Poverty rates in Chad, Cameroon, Niger, and Nigeria

b. Poverty rates in the Lake Chad region

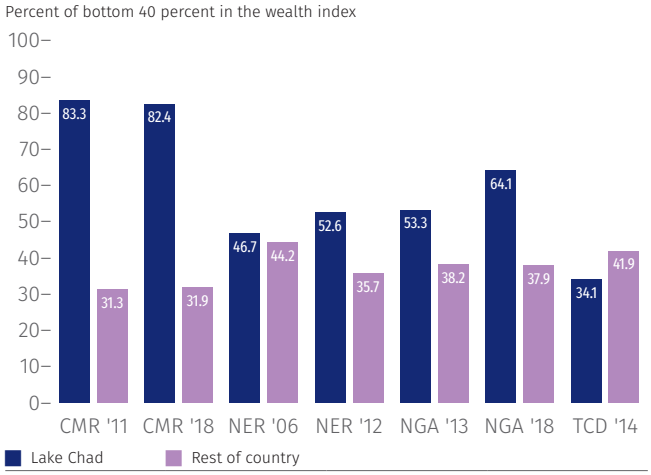
c. Number of poor in the Lake Chad region



Source: Based on the latest household survey in Chad (2011), Cameroon (2014), Niger (2014) and Nigeria (2018).
Notes: Poverty rates calculated at USD 1.90 per day (2011 PPP). The Borno state is excluded given that there is no representative household survey for that state due to security reasons.

Cameroon, for instance, poverty declined by 4 percent in the Extreme-North region compared to a 6 percent decrease in the rest of the country between 2007 and 2014. While Niger as a whole saw a reduction in poverty from 51 percent to 45 percent between 2011 and 2014, its Lake Chad region experienced a slight increase in poverty from 48 percent to 52 percent. This pattern of non-convergence in welfare is also corroborated considering household assets across different regions in each country. The percent of households that are relatively asset-poor—or in the bottom 40 percentile of asset wealth distribution in a given survey year/country[209]—shows no clear sign of convergence between the Lake Chad and non-Lake Chad areas of each country (Figure 2.3). For instance, in Niger and Nigeria, the percent of asset-poor households increased in the Lake Chad region over time, while in Cameroon, this share remained almost unchanged between the two latest rounds of DHS. These findings suggest that wealth gaps between the Lake Chad region and the rest of the countries may have worsened over time.

Figure 2.3: Asset deprivation in the Lake Chad basin versus the rest of the countries



Source: Based on the latest two rounds of Demographic and Health Survey (DHS) in each country.
Notes: The x-axis in the figure includes country names (CMR=Cameroon; NER=Niger; NGA=Nigeria; TCD=Chad) as well as year in which DHS was conducted.

209 We constructed the wealth index for the latest two DHS surveys in each of the LCB countries. Our wealth index is a composite measure of various household assets, including housing materials, access to electricity, cooking fuel, access to improved water, as well as ownership of various items such as televisions and bicycles. We applied a principal component analysis to generate the composite index. To make our wealth index comparable over time within the same country, we applied the same coefficients for use as weights across the two latest surveys. "Asset-poor" households refer to those households whose wealth index score is in the bottom 40 percent of distribution for the given survey country/year.

2.2.2 Local economic dynamics

In addition to lagging behind in terms of core poverty and socioeconomic indicators, the Lake Chad region has experienced little economic progress over the past three decades. An analysis of local economic growth based on nighttime light intensity—which serves as a useful proxy for capturing both the size of local economic activities and its change over time[210]—shows that the intensity of nighttime light is strongly correlated with the distribution of people and economic activities (Map 2.4, Panel A). Overall, nighttime light grew faster in areas that appear to be more densely populated or characterized by higher levels of economic activities (as indicated by nighttime light)—particularly in the Northwest and Southern parts of Nigeria (Map 2.4, Panel B).

Seen from space, the regions near Lake Chad in Cameroon and Nigeria exhibits a relatively low level of luminosity and lower rates of growth. The gaps in the intensity of nighttime light between the Lake Chad region and the rest of the countries are particularly stark in Cameroon and Nigeria whereas in Chad and Niger, the average intensity of nighttime light is slightly higher in the Lake Chad region (Map 2.4, Panel C). The annual rate of growth in nighttime light are also slower in the Lake Chad region compared to the rest of the countries in Cameroon and Nigeria. This implies that there has been no substantial regional growth in the areas around the lake. In Nigeria, in particular, increases in intensity of nighttime light between 1992 and 2013 are much slower in the Lake Chad region compared to the rest of the country (Map 2.4, Panel C and D).

2.2.3 Human capital outcomes and access to basic services

In addition to monetary poverty indicators, the Lake Chad region lags in terms of key human capital indicators. The literacy rate (15 years-old and older) and the completion rate for primary education (ages 14–25) are significantly lower in the Lake Chad region compared to the national average (Figure 2.4). Child health conditions in the region are also grim. For instance, child stunting in the Lake Chad region is roughly 10–15 percent higher in the Lake Chad compared to the rest of the countries (see Table A2.1). These results, based on original analysis performed for this report, are consistent with other studies. For example, according to the International Crisis Group (ICG), the gross school enrolment rate in the Chadian lake area is below 30 percent, and, 'community teachers' (largely pupils' parents) generally stand-in in place of trained teachers.[211] In the Chadian part of the lake, there is only one doctor for every 140,000 inhabitants, that is, a quarter of the national average.[212] The low access and quality of education, health and other services in the region has been aggravated by the erosion of infrastructure, both public and private, resulting from the conflict.[213]

Access to core public services in the Lake Chad basin is also lower than in the rest of the countries.. For instance, the national average rate of access to electricity in Cameroon, Chad, Niger, and Nigeria is 62 percent, 8 percent, 14 percent and 59 percent, compared to an estimated 20 percent, 2 percent, 10 percent and 38 percent in the Lake Chad region, respectively. In terms of access to improved water and sanitation facilities, the Lake Chad areas of Cameroon and Chad suffer from lower levels of access compared to the rest of the country (Figure 2.5).

210 The analysis of nighttime light relies on Defense Meteorological Satellite Program (DMSP) OLS data that are inter-calibrated by Li et al. (2020), allowing for a better comparison over time. The intensity of nighttime light is measured in a digital number (DN) ranging from 0 and 63 that represents an average of lights in all nights after sunlight, moonlight, aurorae, forest fires, and clouds have been removed algorithmically, leaving mostly human settlements.

211 ICG (2017).

212 Ibid. The figure for Chad is much lower than in Cameroon's Far North region (1/52,000) or Niger's Diffa region (1/24,500), both close to the lake.

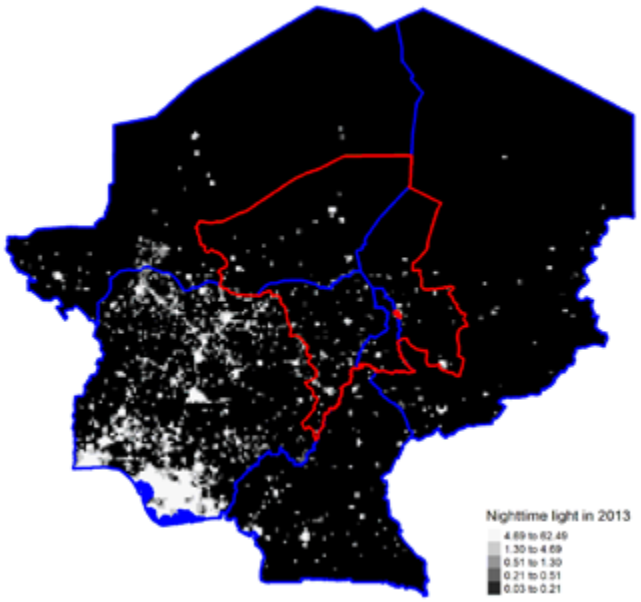
213 It is reported that, during the armed group's eight-year rebellion, almost 1,400 schools have been destroyed in Borno and more than 57 percent of schools are unable to open because of damage or being in areas that remain unsafe (Al Jazeera 2017). Regarding health facilities: "Insurgents have destroyed about 788 health facilities in the region. In Borno 48 health workers have been killed and over 250 injured. The state has lost up to 40 percent of its facilities and only a third of those left in Borno state remain functional," (Obi and Eboreime 2017).

This gap is particularly pronounced in Cameroon, where the rate of access to improved water and sanitation in the Far North region is, on average, about 36 percent lower than the rest of the country.

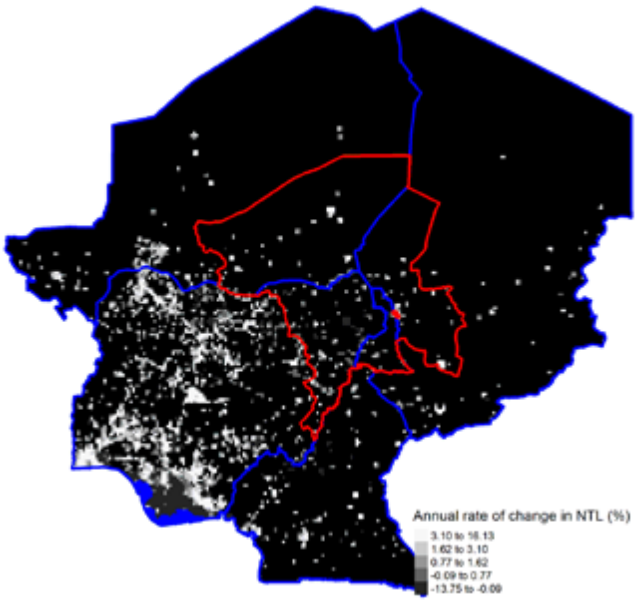
There are also signs of a *widening* gap between the Lake Chad and the rest of the surrounding countries in terms of access to improved sanitation and electricity. In Cameroon, the share of households with access to improved sanitation in the Lake Chad region declined

Map 2.4: Widening gap in economic dynamics between the Lake Chad region and other parts of the countries, 1992–2013

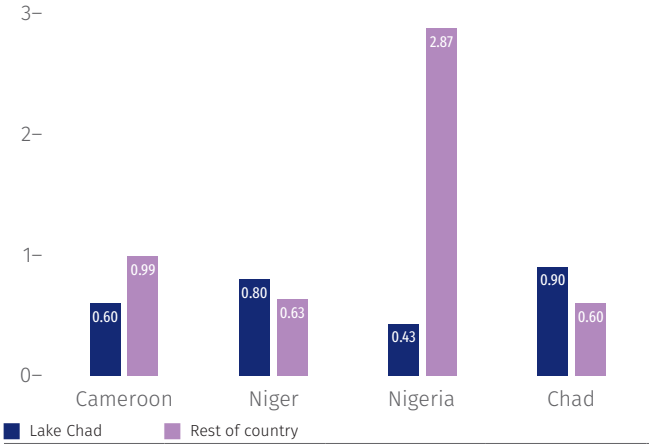
a. Nighttime light intensity, 2013



b. Annual rate of change in nighttime lights, 1992–2013

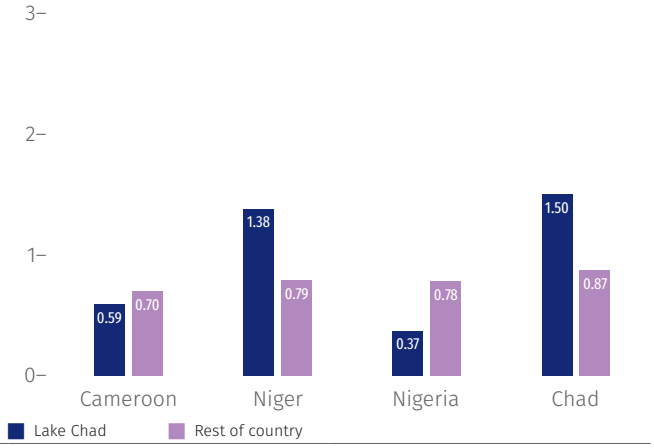


c. Nighttime light intensity in comparison between the Lake Chad region and other parts of the countries



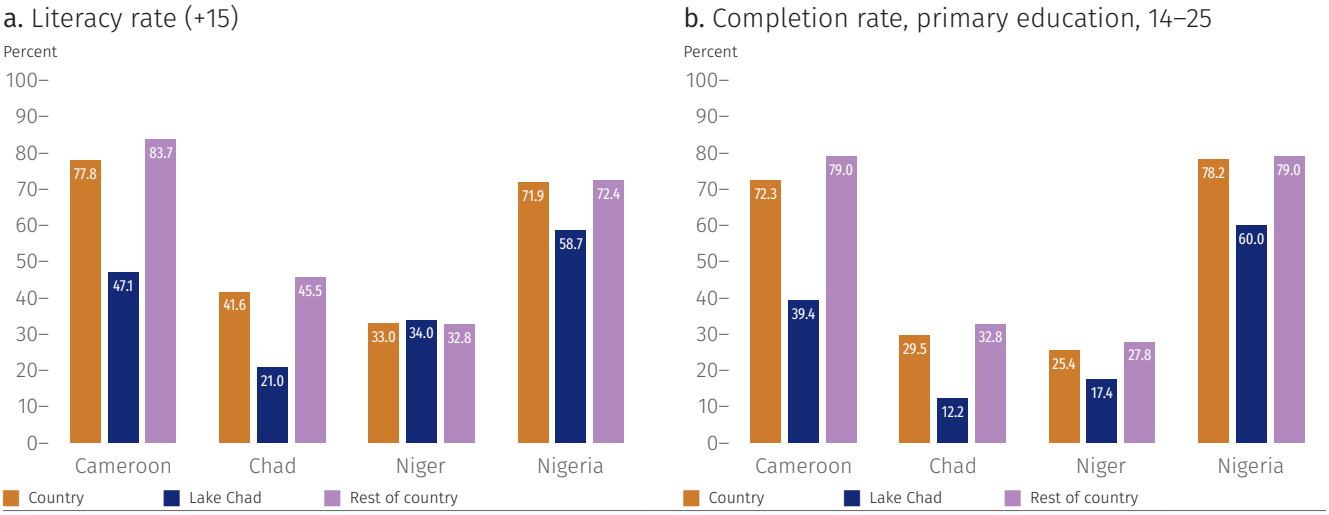
d. Change in nighttime light in comparison between the Lake Chad region and other parts of the countries

Annual rate of change, 1992–2013, percent



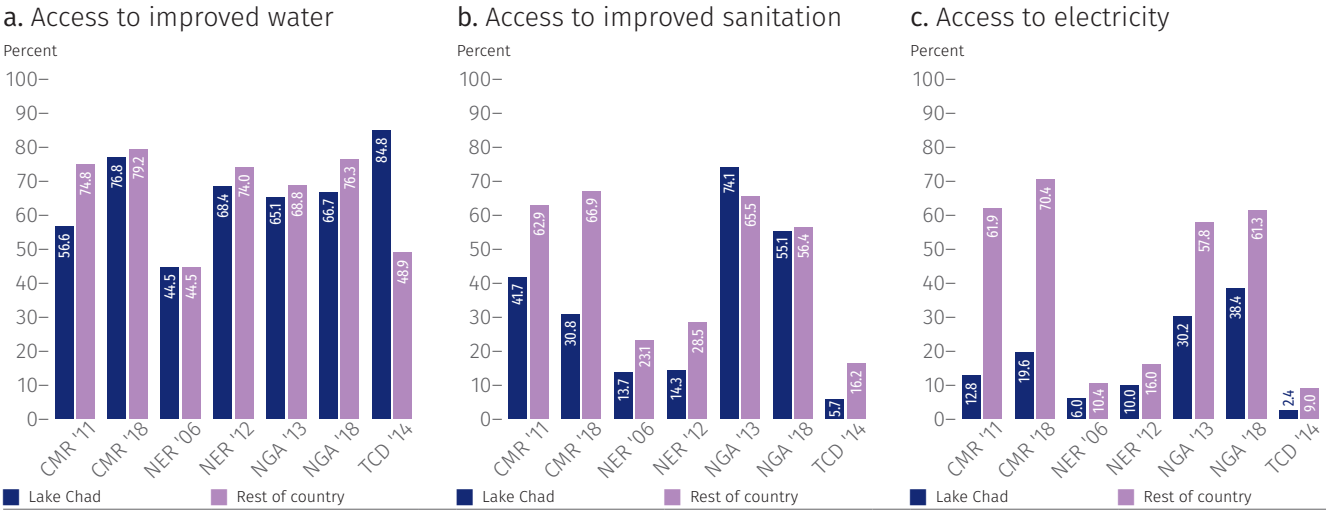
Source: Panel A shows the mean of nighttime luminosity for 2013 based on stable DMSP inter-calibrated NTL data (Li et al. 2020) at a spatial resolution of 10km while Panel B shows the annual rate of growth in the mean of nighttime luminosity between 1992 and 2013 in percent. Panel C and D show the mean of nighttime light luminosity and annual rate of change in nighttime light luminosity (in percent) during the same time period. The calculation for Panel C and D was performed only on a subset of grid cells that are lit (with a positive value in digital number at some point between 1992 and 2013) thus excluding areas that are largely rural and unpopulated.

Figure 2.4: The literacy and completion rates for primary education in the Lake Chad are significantly lower than in the rest of the countries



Sources: Based on the most recent household surveys conducted in Cameroon (2014), Chad (2018), Niger (2018) and Nigeria (2018).

Figure 2.5: Access to core public services in the Lake Chad region across time



Source: Based on the latest two rounds of Demographic and Health Survey (DHS) in each country.
Notes: The graph shows the percentage of households with access to improved water and sanitation and electricity from left to right. Data on access to these core public services are taken from the two latest DHS in each country. The x-axis in the figure includes country names (CMR=Cameroon; NER=Niger; NGA=Nigeria; TCD=Chad) as well as year in which DHS was conducted.

from 42 percent to 31 percent between 2011 and 2018 whereas the rest of the country experienced a modest improvement (from 62 percent to 67 percent) over the same period. A similar divergence pattern emerges in Nigeria, where access to improved sanitation in the Lake Chad area decreased from 74 percent to 55 percent between 2013 and 2018—a much faster rate of decline than in the rest of the country (where access fell from 66 percent to 56 percent). Progress in expanding access to electricity in the Lake Chad region has also stagnated. In Niger, the regions of Diffa and Zinder saw access to electricity improve by four percentage points (from 6 to 10 percent) between 2006 and 2012, a slightly lower increase than in the rest of the country (where access improved by nearly six percentage points, from 10.4 percent to 16 percent) (Figure 2.5).

2.3 Spatial Dynamics of Economic Development within the Lake Chad Region

2.3.1 Density

The perpetuation of poverty and slow growth in the Lake Chad region is closely linked to its economic geography (WDR 2009). Indeed, the combination of *low* economic density as well as *high* distance and division coalesces to detail the region from its sustainable growth path.

The region is characterized by a low economic density and a lack of agglomeration economies that hinders it from reaching its potential. While the Lake Chad region accounts for 17 percent of total areas of the four neighboring countries combined, its economy makes up only 5 percent of GDP.[214] Most economic activities in the region are highly spatially concentrated in a few large and secondary cities. Beyond N'Djaména and Maiduguri—only two metropolitan cities with a population of over 1 million—there are several secondary cities that support the economy of the region, including Damaturu (Nigeria), Jimeta (Nigeria), Mubi (Nigeria), Maroua (Cameroon), Zinder (Niger) among others. Estimates of Gross National Product (GDP) for the Lake Chad region show that economic activity is spatially concentrated in these few urban centers which are clustered around the national borders of the neighboring countries (Map 2.5).

Most of the trade between Nigeria and Cameroon flew through the corridor connecting Maiduguri to Kousseri or Maroua although this trade flow has been significantly disrupted by the intensification of the Boko Haram conflicts since 2009[215] (and more recently since Nigeria closed its land borders in August 2019).[216] In Cameroon, most of the economic activities in the Lake Chad region are clustered in the southern part of Extrême—Nord, particularly around the city of Maroua.[217] In Niger and Chad, while the volume of economic activities in the Lake Chad areas is small, they tend to also cluster around the border areas neighboring Nigeria and Cameroon.

Local agricultural systems have been also disrupted following the destruction of farming and irrigation facilities. Conflict and violence that escalated since 2009 have generated losses equivalent to an estimated USD 3.7 billion, including profound loss of fisheries, livestock, and agricultural production, ruined irrigation and farming facilities, and the collapse of extension services.[218] Insecurity is exacerbating the existing challenges faced by vulnerable farmers who were already facing devastating natural hazards including cyclical droughts and floods. The concentration of herds due to changes in transhumance flows as a result of these climatic conditions is putting pastoral resources under extreme pressure and threatening animal health.

2.3.2 Distance

While leading areas tend to have a high economic density, lagging areas tend to present a long distance-to-density ratio. *Distance* refers to the ease or difficulty for goods, services, labor, capital, information and ideas to traverse space. It measures how easily capital flows, labor moves, goods are transported, and services are delivered between two locations. In this sense, distance

214 Calculated based on Ghosh et al. (2010).

215 In a study conducted by WFP (2016), only one out of 26 transporters surveyed in Cameroon reported Nigeria as its main supply source of cereals suggesting that agricultural trade flows between Northeast Nigeria and North Cameroon have been reduced.

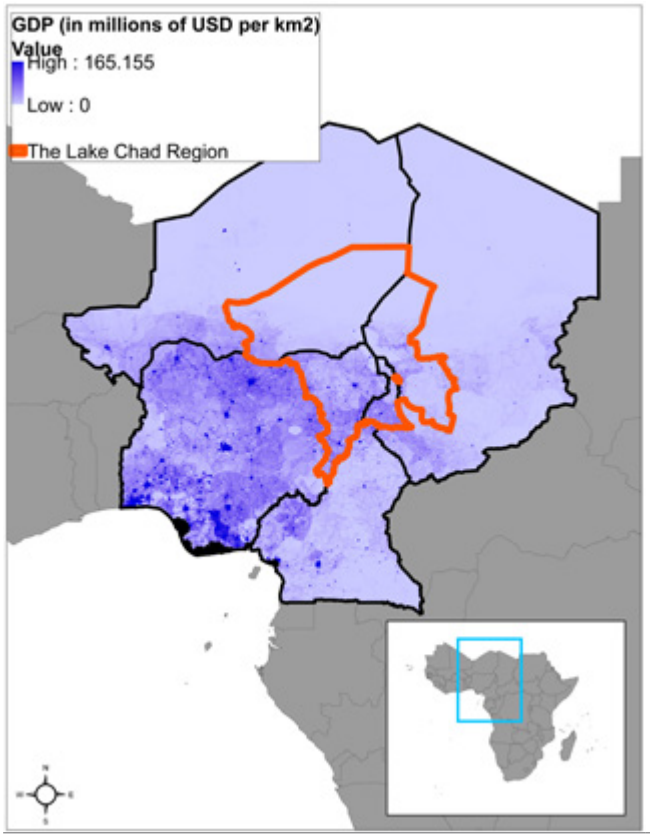
216 The Nigerian government announced on August 22, 2019 the partial closure of three border sites with Benin and Cameroon. The closure was officially extended to all land border crossings in September 2019.

217 See UNHCR and World Bank (2016).

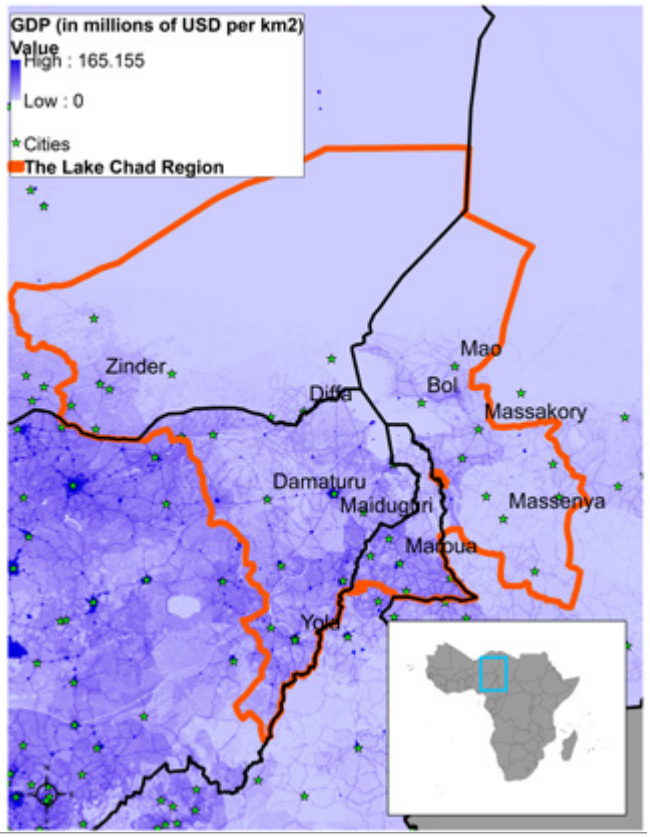
218 World Bank (2020), PROLAC Program Appraisal Document, Report PCBASIC0089548.

Map 2.5: Economic activity in the Lake Chad region, 2006

a. Estimated subnational real GDP (2006) in Cameroon, Chad, Niger, and Nigeria



b. Estimated subnational real GDP (2006) in the Lake Chad region



Source: Authors' calculations based on data from Ghosh et al. (2010).

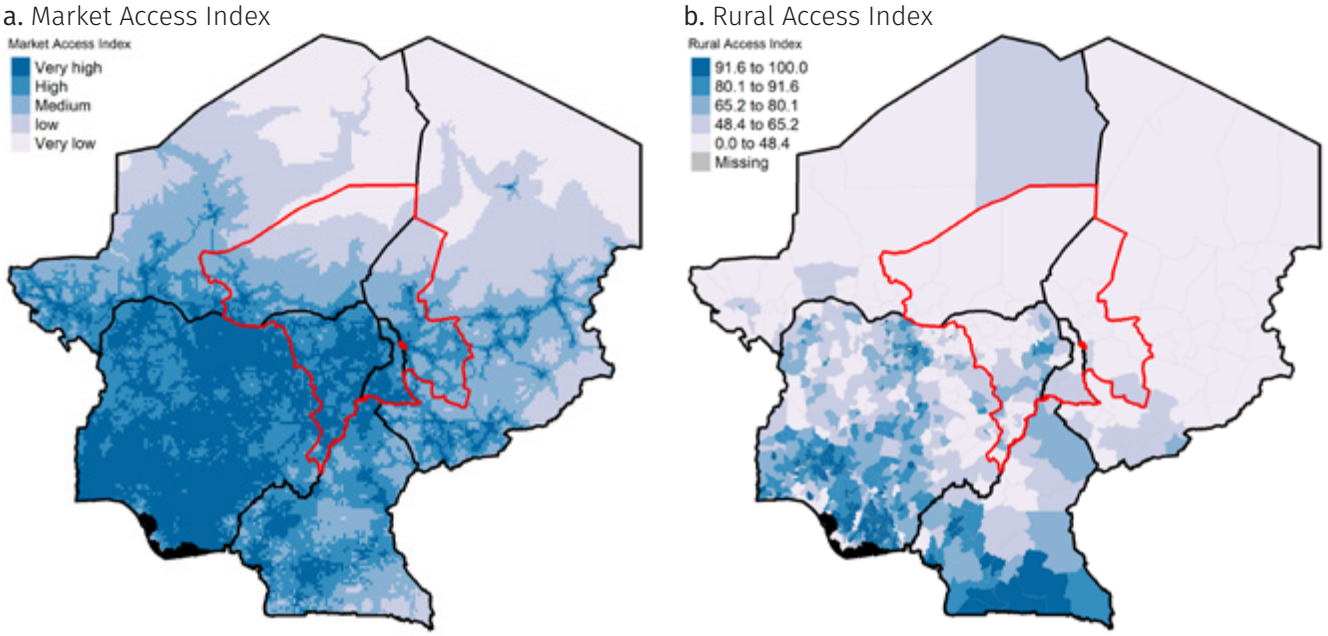
is an economic concept not just a physical one, related to connectivity and access. An area is more likely to be lagging the farther away it is from leading areas since greater distance-to density implies a lack of integration into the economy. It also implies poorer access to the "thick" markets of capital, labor, goods, services and ideas, and the spillovers of knowledge and information they provide.

2.3.2.1 Physical Infrastructure

Access to connective infrastructure across the Lake Chad region is very limited, particularly among the rural population. A large swath of rural areas in the Lake Chad region still have limited access to large markets. These areas—with a long distance-to density ratio—are characterized by slower growth in economic activities. Poor road infrastructure undermines intra- and inter-regional connectivity across the region, limiting economic opportunities for people. This is further compounded by rising transportation costs in water transportation, partly driven by government interventions limiting boat circulation in the lake, and the drying of the lake. Conversely, areas proximate to population centers tend to have greater market accessibility due to a wider and denser road network system, allowing people living near a city to benefit from its agglomeration economies.

Rural people in the Lake Chad region are twice as likely to be disconnected from all-seasons roads (motorable all year round), compared to areas in the rest of the countries. The Market Access Index–a measure of the size of population that can be reached within a certain

Map 2.6: Market and rural access in and around the Lake Chad region



Source: Calculated by the authors on various geospatial data sources (see Appendix 2.C and 2.D for further details).
Notes: The map on the left shows areas that score "very high" (top 20 percentile), "high" (20–40 percentiles), "medium" (40–60 percentiles), "low" (60–80 percentile), and "very low" (bottom 20 percentile) in the Market Access Index. See Appendix 2.C for further details on how the Market Access Index is calculated. The map on the right shows the Rural Access Index or share of rural population who live within 2 km away from all-season roads as proxied by *OpenStreetMap*. See Appendix 2.D for details on the construction of the Rural Access Index.

travel time–is relatively high in the Lake Chad region compared with some other parts of the countries (Map 2.6, Panel A). This indicates that, with proper connective infrastructure, people in the Lake Chad region could benefit from economic opportunities that large markets—both within and around the region—can offer. However, the score of the Rural Access Index—i.e. the share of rural population living within 2 km away from an all-season road[219]—is low for the region (Map 2.6, Panel B). Nearly two thirds (about 60 percent) of the rural population in the Lake Chad region live farther than 2 km away from an all-season road (proxied by *OpenStreetMap*), that is, about twice the share in the non-lake parts of the basin countries (about 30 percent).

2.3.2.2 Digital Infrastructure

Poor road connectivity in the Lake Chad region is further complicated by a lack of digital infrastructure. Cell phone ownership as a share of population in the areas bordering the lake in Niger stood at 13.4 percent compared to 20 percent for the rest of the country. A similar pattern can be seen in Nigeria, where cell phone ownership is 4.7 percentage points lower in the regions bordering the lake. Chad is the only exception, where ownership is higher in areas bordering the lake compared to the rest of the country (20 versus 15.6 percent). However, the share of people who are connected is still low compared to international standards, translating to roughly 80 percent of the population being disconnected from digital technologies.

219 An "all-season road" is defined as a road that is motorable all year round by the prevailing means of rural transport. Trunk, primary, secondary, and tertiary roads in *OpenStreetMap* are used as a proxy for all-season roads following the methodology by Azavea: https://rai.azavea.com/.

The lack of digital infrastructure and low levels of cellphone ownership hinder the adoption and usage of novel digital technologies. While digital infrastructure in Sub-Saharan Africa as a whole is lagging behind compared to the rest of the world,[220] the Lake Chad countries have a particularly low level of internet penetration. Approximately 11.8 percent of the population in countries bordering Lake Chad reported using the internet, compared to 18.7 percent across Sub-Saharan Africa, on average.[221] There is heterogeneity within the region. Chad lies among the countries with the lowest internet penetration rates in the world, at 6.5 percent of the population, compared to Cameroon, which at 23.2 percent ranks above the regional average. A similar pattern can be seen regarding mobile internet penetration—measured by unique mobile internet subscribers[222]—which is the main mechanism of access to the internet in Sub-Saharan Africa (as opposed to fixed-broadband subscriptions).

Mobile internet in the LCB countries has undergone a rapid expansion, although its pace still lags regional leaders like South Africa. Unique mobile internet subscribers across the Lake Chad region increased almost twofold as a share of the population between 2014 and 2020. In 2020, this figure stood at 31.1 percent of the population, above the regional Sub-Sahara African average of 27.7 percent. However, the share of unique mobile internet subscribers in the Lake Chad countries remains substantially below regional leaders, such as South Africa (52 percent). Chad registered a unique mobile internet subscription rate of 17.1 percent of the population in 2020, compared with 34 percent in Nigeria and 33.8 percent in Cameroon. On the other hand, Niger has the lowest mobile internet penetration rate across the Lake Chad region, and among the lowest in Sub-Saharan Africa. It is important to identify the main constraints to adopt internet services faced by individuals to fully harness the potential benefits of digital technologies in the region.

The Lake Chad region is largely disconnected from the digital world.[223] A large swath of areas in the Lake Chad region has very little connectivity to fiber optics transmission nodes[224] or 3G technology[225] except for the Extreme North region of Cameroon where there appears to be more comprehensive coverage (Map 2.7).[226] Access to the internet (either through fixed broadband or mobile broadband) can serve as a catalyst for poverty alleviation,[227] improved labor outcomes[228] and the functioning of rural markets,[229] specifically regarding price information, access to inputs and consumers[230] and access to capital

220 World Bank (2019).

221 Data of 2017, WDI (World Development Indicators) (database) (accessed on 04/07/2021), World Bank, Washington, DC, https://datatopics.worldbank.org/world-development-indicators/. Internet users are individuals who have used the internet (from any location) in the last 3 months. The internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.

222 Given that consumers may use multiple SIM cards to take advantage of discounts or to avoid high charges for off-network calls, market penetration in terms of unique subscribers may provide a better picture of the degree of access to mobile services. GSMA defines mobile internet as the use of internet services by unique users on mobile devices at the end of a given period. Mobile internet services are defined as any activity that uses mobile data (that is, excluding SMS, multimedia messaging services, and cellular voice calls). See GSMA Intelligence (database), Global System for Mobile Communications (GSM Association), London, https://www.gsmaintelligence.com/. Accessed on April 7 2020.

223 Hjort and Poulsen (2019).

224 These nodes correspond to add or drop points (entrance or exit) in the long-haul fiber networks. It is useful to think of long-haul fiber networks as motorways that have junctions (on and off ramps that is, add and drop points) that feed smaller class roads (access fiber, wireline, and wireless networks). In the motorway scenario, even if a household is located close to the motorway, it may be a long drive to the nearest junction. The same applies to fiber-optic networks, in which the speed of fixed broadband Internet is determined by proximity to the transmission nodes rather than the network lines connecting the nodes.

225 While second-generation (2G) technologies enable voice, SMS, and limited Internet access, third-generation (3G) technologies enable more rapid Internet browsing and data downloading.

226 The 2G/3G coverage data should be treated with caution, however, because the Collins Bartholomew coverage maps do not necessarily include all network providers in each country and comparing coverage across these countries may be problematic due to uneven reporting of coverage by country. Overall, this coverage map should be treated as a lower bound of 2G/3G availability.

227 See Bahia et al. (2019) and Masaki et al. (2020).

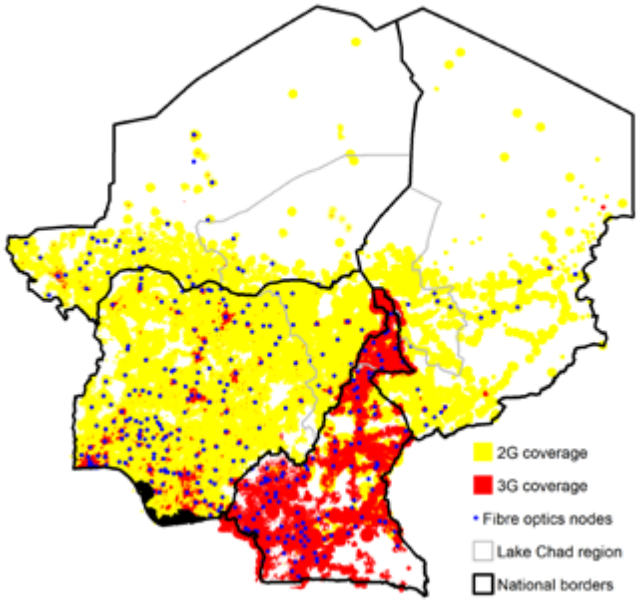
228 See Hjort and Poulsen (2019); Paunov and Rollo (2014); Fernandes et al. (2019); Chun and Tang (2018); Viollaz and Winkler (2020).

229 See Kaila and Tarp (2019); Goyal (2010); Ritter and Guerrero (2014); Salas-Garcia and Fan (2015).

230 See Aker and Mbiti (2010); Aker (2011); Debo and Van Ryzin (2013).

markets.[231] Poor digital connectivity around Lake Chad is thus another important source of distance that prevents the region from tapping its full economic potential.

Map 2.7: Digital connectivity in and around the Lake Chad region (2018–2019)



Source: Data on 2G/3G coverage maps from Collins Bartholomew coverage maps; data on the locations of operational fiber optics nodes from Africa Bandwidth Maps http://www.africabandwidthmaps.com/.
Notes: Mobile coverage corresponds to 2018. Fiber optics correspond to 2019. The 2G/3G coverage data should be treated with caution, however, because the Collins Bartholomew coverage maps do not necessarily include all network providers in each country. Thus, this coverage map should be treated as a lower bound of 2G/3G availability.

2.3.3 Division

Together with density and distance, the third important geographic dimension for territorial development is division. It applies at both national and international scales. At the national scale, nations can be internally divided across linguistic, ethnic, religious, and/or cultural lines. At the international level, divisions mainly arise from so-called thick borders, i.e., the many restrictions countries impose on other countries regarding the flow of goods, capital, people and ideas.[232] Thick borders limit trade and the flow of factors of production. Interstate conflict creates the thickest borders. While borders in the rich world have become increasingly thin, hereby facilitating trade and the movement of people and capital, borders in many developing countries remain thick, as is generally the case in the Lake Chad region. At the same time, borders in the areas around Lake Chad have historically been characterized as relatively porous—with trade and social ties permeating borders. This mobility, however, has subsided over the last decade with the hardening of borders and counterinsurgency measures as a response to the Boko Haram insurgency.

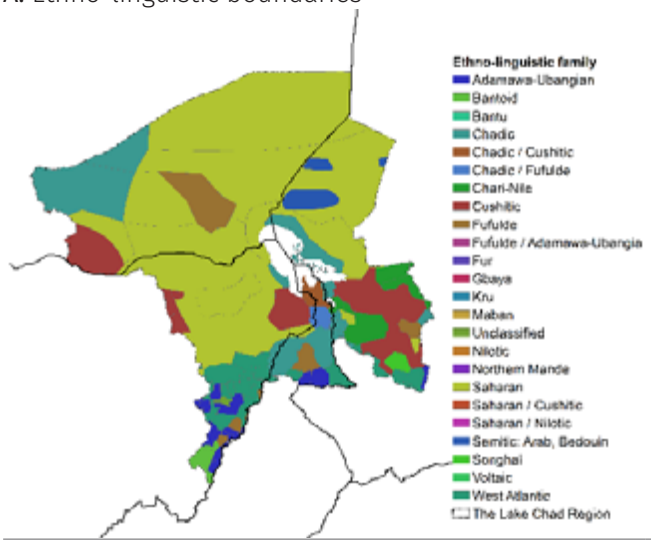
2.3.3.1 Ethnolinguistic and religious divisions

The roots of conflict and intercommunal violence in the Lake Chad region are found in multi-faceted factors ranging from competition over resources, local tensions and differences between ethnic groups in the Lake Chad region, as well as climate shocks. As shown by the ethno-linguistic boundaries mapped below (Map 2.8, Panel A) the Lake Chad region presents a wide ethnic heterogeneity.[233] The basin has also been subject to tensions stemming from wide religious diversity. Different religious groups concentrate in the area, ranging from the predominantly Muslim-majority northern Basin in Niger, to a less concentrated Muslim majority in northeast Nigeria and Kanem in Chad, to a Christian majority in the Extreme–North region of Cameroon and the Hadjer Lamis and Chari Baguirmi regions in Chad (Map 2.8, Panel B). Some of the Boko Haram violent activities may be linked with pre-existing tensions between specific local communities or ethnic groups.[234] What may be referred to as 'another attack by Boko Haram' in Lake Chad in the international media, may instead be a set of reprisals among the Kuri, livestock farmers, and fishermen.[235] Changes in land use and

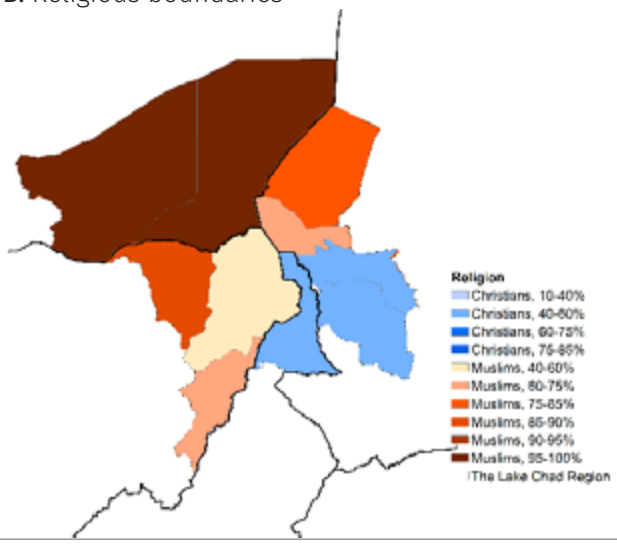
231 See Hasbi and Dubus (2019); Alibhai et al. (2018).
232 Fratianni and Kang (2006).
233 Vedeld (1999).
234 Cohen (2015).
235 Ibid.

Map 2.8: Ethnolinguistic and Religious Groups in the Lake Chad region

A. Ethno-linguistic boundaries



B. Religious boundaries



Source: Elaboration based on Ethnicity Felix 2001 and World Religion Map from Harvard Worldmap.

water resource management since the 1980s, coupled with ineffectiveness in the fragile local institutions have led to heightened competition among farmers, herders and fishers along social fault-lines of ethnicity, religion, gender, and class.[236,237]

2.3.3.2 Boko Haram Conflicts

The intensification of conflict in the Lake Chad region since the rise of Boko Haram in 2009 has been a large source of division driving the leggedness of the region. While the group was fist founded in 2002, the insurgency is considered to have begun in full in 2009 in Nigeria with bases in neighboring countries. In 2014–2015, it expanded into northern Cameroon, Niger and Chad. Since then, the group has retreated into inaccessible areas, mainly along the borders, but has continued to carry out more frequent and sophisticated attacks.[238] Boko Haram has been aligned with the Islamic State of Iraq and the Levant since 2015.[239] It is not a unified group; in 2016 it split into two factions: the Islamic State's West Africa Province (ISWAP) and Jama'atu Ahl al-Sunnah lil-Dawa wal-Jihad (JAS).[240] At its peak—that is between 2010 and 2015—the group seized a large swath of territories in Northeastern Nigeria, including major cities, pushing the Government of Nigeria to declare a state of emergency, (an action that was later followed by other governments in the region). While most of the attacks between 2009 and 2013 were geographically concentrated in a few states in the Northeastern corner of Nigeria, the terrorist group moved some of its activities to the neighboring areas of Cameroon, Chad and Niger (Map 2.9). Vigilante groups have been created in response to the insurgency, which are becoming increasingly violent.

The ethnolinguistic divisions exacerbated with the crisis are associated with social exclusion. For example,

236 Onuoha (2010), Béné et al. (2003), Ahmadu (2011).

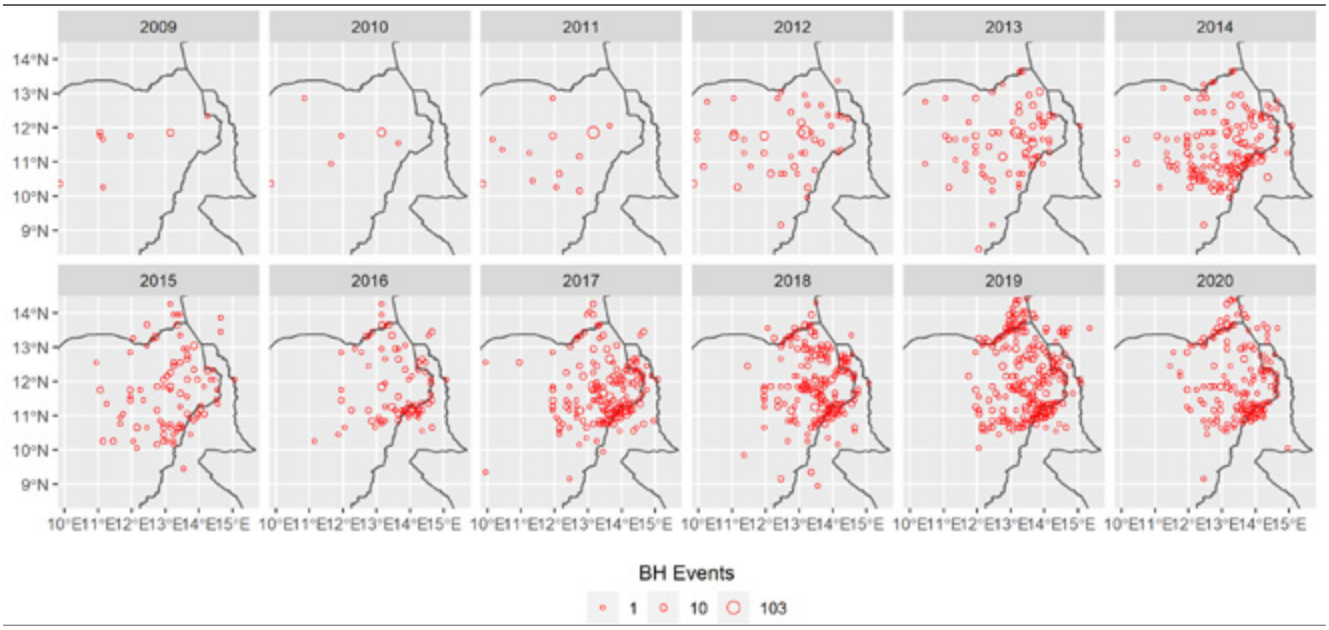
237 Smith and Walters (2017).

238 Magrin and Perouse de Montclos (2018).

239 Vivekananda et al. (2019).

240 The indiscriminate targeting of civilians appears to have been a major point of disagreement. The extremist group ISWAP avoids harming civilians, focusing mainly on military and government targets (Samuel 2019).

Map 2.9: The evolution of the number of Boko Haram violent events from 2009–2020



Sources: Blankespoor (2021). technical paper for this report. The elaboration is based on ACLED (Armed Conflict Location and Event Data Project) (dashboard), Robert S. Strauss Center for International Security and Law, Austin, TX, http://www.acleddata.com/.

Kanuris, who are viewed as Boko Haram sympathizers, have increasingly become the subject of discrimination in Cameroon's Far North region. Anecdotal evidence suggests that the ethnic group is targeted both by security forces as well as by local militias groups, or vigilantes, for their perceived connection to the Boko Haram insurgency. In turn, this has been associated with social exclusion and marginalization of the group, affecting individuals' ability to participate in economic activities. On the other hand, the conflict has also had an impact on social cohesion *within* communities. For example, individuals forcibly displaced in host communities in Cameroon live together but compete for the same services, which are already strained in terms of both access and quality. The conflict has also led to distrust among communities in connection with former fighting.

2.3.3.3 Cross-border trade

Cross-border trade has declined as a result of the insurgence. Conflict has affected production and trade directly, as well as indirectly, through the counter-insurgency measures that restrict movement and put bans on farming and trade.[241] Transit flows of livestock seem to be declining. The transit of cattle to Nigeria from Chad and Cameroon decreased by 39 percent between 2015 and 2016–2017, as shown by customs data from the Yagoua livestock crossing point.[242] The deteriorating impact that the conflict has had on Chad's livestock exports to Nigeria is even more poignant considering that these exports are the country's second source of foreign revenue after oil.[243] In Cameroon, estimates suggest that Boko Haram has stolen USD 6 million dollars' worth of cattle, sheep and goats since 2013.[244] Market infrastructure has also been subject to physical damage, e.g. in Damaturu in Yobe, Nigeria, over 650 shops have been reported as damaged.[245]

241 UNDP, OCHA (2016).
242 World Bank (2018).
243 World Bank (2015).
244 World Bank (2018).
245 Mercy Corps et al. (2017).

2.4 Determinants of regional growth

There is a multitude of structural factors and aggregate shocks that could affect a trajectory of territorial development in the Lake Chad region. As discussed earlier, not only does it fall behind in terms of its core poverty and socio-economic indicators compared to other parts of the countries, the Lake Chad region also has seen very little economic progress over the past three decades (see Section 2.2). This section seeks to identify these factors that might be associated with the dynamics of economic activity across the region using an econometric approach.

The analysis employs multivariate regression to tease out which of these factors contribute to regional growth. More formally, following Barro and Sala-I-Martin's and Bairro et al.'s (1995), the following convergence model is estimated:

$$G_{jrct1\text{-}t0} = \alpha + \beta_1 \ln(Light_{jrct0}) + \beta_2 \, Lake\ Chad\ region_{jrc} + \beta_3 X_{jrct} + C_r + \varepsilon_{jrct} \quad (1)$$

where $G_{jrct1\text{-}t0}$ corresponds to annual growth rate in nighttime light intensity between year $t0$ and year $t1$ in 0.1 degree (≈11 km × 11 km) grid cell j in region r in country c. More formally:

$$G_{jrct1\text{-}t0} = \ln(Light_{jrct1}/Light_{jrct0}) / (t1\text{-}t0) \quad (2)$$

where $Light_{jrct0}$ denote the initial level of nighttime light at $t0$ and β_1 essentially captures the rate of convergence after accounting for other confounding factors X_{jrct} There is conditional convergence (divergence) if β_1 is statistically significant and negative (positive). Also included in this regression is a dummy variable coded 1 if a given grid cell lies within the boundary of the Lake Chad region, 0 otherwise. In essence, if β_2 turns out to be statistically significant and positive (or negative), it shows that areas in the Lake Chad region experienced faster (or slower) growth in nighttime light vis-à-vis other parts of the countries surrounding the lake. X_{jrct} contains a wide range of conditional variables that seek to capture various potential factors that could affect the trajectory of local economic growth. More specifically, it includes population, weather shocks, conflicts, market accessibility, as well as various other geographical features, including the density of cropland (as a proxy for agricultural production) and grazing land, access to on-grid electricity, elevation and terrain constraints.[246] Lastly, the model controls for region (or ADM1-level) fixed effects C_r to ensure that our results are not confounded by time-invariant regional characteristics as well as longitude and latitude of each grid to account for other geographical confounders.

To better understand which factors contribute most significantly as drivers for local economic growth, we report the results of a Shapley decomposition from those regressions.

2.4.1 Data

Given the dearth of data, we turn to various geospatial datasets to capture a multitude of structural factors that may drive local economic growth. Our full sample consists of 32,097 0.1×0.1 grid cells defined over the four countries of Cameroon, Chad, Niger and Nigeria. We then look at a subsample of cells that exhibited some level of luminosity at some point between 1992 and 2013—the period for which nighttime light data are available and comparable over time—and we refer to this subsample as an "intensive" margin sample. The intensive margin sample can be considered as a set of cells that

246 See Appendix 2.B for descriptive statistics of variables used in the regression.

exclude uninhabited areas or largely rural areas with no luminosity observed from space. The intensive margin sample includes 5,211 cells.

Nighttime light

Our proxy measure for local economic growth comes from satellite data on light emitted into space at night. Meteorological Satellite Program (DMSP) have been recording data on lights at night using their Operational Linescan System (OLS) sensor since the mid-1960s, with a global digital archive beginning in 1992. DMSP-OLS nighttime light data are available on an annual basis for the period of 1992–2013 and at a resolution of roughly 1km (30-arcsecond pixel). The strength of luminosity at night is measured by a digital number (DN), an integer between 0 and 63, which represents an average of lights in all nights after sunlight, moonlight, aurorae, forest fires, and clouds have been removed algorithmically, leaving mostly human settlements. Given that the original DMSP NTL time series data are not comparable across years due to the lack of on-board calibration, varied atmospheric conditions, satellite shift, and sensor degradation, we rely on inter-calibrated DMSP NTL time series data from Li et al. (2020).

Population

Our grid-level population data derives from the Global Human Settlements (GHS). GHS use satellite data to obtain for each cell built-up land area over time, more precisely circa 1975, 1990, 2000 and 2013/14, which nicely coincides with the end of our period of study. Furthermore, GHS reconstructs grid-level populations circa 1975, 1990, 2000 and 2015, using population levels at a relatively low administrative level circa these years and then allocating the population within these administrative areas depending on the distribution of built-up land area.

Climate data

Our main climate indicator is the Standardized Precipitation-Evapotranspiration Index (SPEI), developed by Vicente-Serrano et al. (2010). SPEI takes into account both precipitation and potential evapotranspiration or the ability of the soil to retain water, which depends on temperature, latitude, sunshine exposure, and wind speed. SPEI data are drawn from the Global SPEI Database (https://spei.csic.es/). SPEI is expressed in units of standard deviation from the cell's historical average and thus has mean 0 by construction in the historical sample.

Since the impact of rainfall on local economy—and agriculture for that matter as the entire economy of the region relies heavily on the agricultural sector—is most likely much larger during the growing season, we consider SPEI specifically for growing periods in each cell. To identify a cell-specific growing period, we follow Harari and La Ferrara (2018) and rely on the MIRCA 2000 crop calendars data set (Portmann et al. 2010). This dataset offers harvest areas by crop and start and end months of growing seasons for each crop (available at a spatial resolution of 5 arc-minute or roughly 9km at equator). We first identify the main crop for each cell based on harvested areas according to the MIRCA 2000 crop data and then match with the growing month calendar for those cell-specific major crops. Finally, we average monthly SPEI values for the growing season months of a cell's main crop in a given year. Higher values of this variable correspond to more favorable conditions for local agriculture. For areas that are considered to be largely non-agricultural or pastoral, we use the annual average SPEI.

Access to gridded electricity

Data on gridded electricity comes from *GridFinder*, an open source tool for predicting the location of electricity network lines.[247] Arderne et al. (2020) constructed the composite map of the global power grid by applying multiple filtering algorithms to night-time light imagery to identify locations most likely to be producing light from electricity. These light sources (target-locations) are then connected to known electricity networks through a

247 Data can be downloaded from https://gridfinder.org/

least-cost routing algorithm following roads and known distribution lines (adopted from *OpenStreetMap*).

Conflict data

Conflict data is from the Armed Conflict Location and Event Data Project (ACLED) (Raleigh et al., 2010). We categorize the conflict data by actor into "Boko Haram" and "non-Boko Haram" observations.[248] Using the data, we construct the cell-specific number of conflict events and number of fatalities.

Market access

We construct the index of market accessibility, which is the weighted sum of population in all the major markets or urban agglomerations, which are weighted by travel time/distance. See Appendix 2.C for details on data sources and methodology used to construct this index.

Cropland and grazing land

Data on cropland and grazing land derive from the HYDE 3.2 panel dataset (Goldewijk, 2017), which provides a spatial estimation of cultivated land (excluding urban areas and pasture land) for each of our grid cells. The HYDE 3.2 data on land classification is generated based on satellite imagery of land use and is available at a spatial resolution of five arc-minute or 10 km by 10 km for the period between 10 000 before Common Era (BCE) to 2015 Common Era (CE).

Elevation and terrain slope constraints

Data on elevation and terrain constraints for farming come from SRTM data Version 4 (Jarvis et al. 2008) and the Global Agro-Ecological Zoning (GAEZ) database. Elevation data are available at a spatial resolution of 90m. GAEZ data on terrain slope constraints classifies the level of constraints to a given area or grid cell into seven different categories from 0 (no constraints) to 7 (severe constraints) and distribution of these classes were defined for each 30 arc-second grid cell (or about 1km).

2.4.2 Results

Table 2.1 presents the main results and Table 2.2 reports the results from a Shapley decomposition of the regressions. We find clear evidence that overall there is a sign of *conditional* convergence in terms of economic activities as captured by nighttime light. More substantively, the level of economic activities grew more quickly in less-developed areas by an annual convergence rate of 1 percent between 1992 and 2013 after accounting for other potential confounders including population size and population growth. It is worth highlighting that the coefficient for the Lake Chad dummy is close to zero and far from significant. What this implies is that there is little sign of divergence or convergence between the Lake Chad region and rest of the countries overall conditional on the initial level of development and other demographic, geographic and socio-economic factors. Within the Lake Chad region, we did not see any sign of convergence.

The growth of nighttime light is strongly driven by population density and its growth over time both across the four countries and within the Lake Chad. This perhaps does not come as a surprise because nighttime lights are both a function of population density as well as economic activities.[249] Indeed, the initial level of nighttime light luminosity and population altogether explains roughly 15–20 percent in the intensive margin and full samples covering the four countries though their explanatory power is much smaller within the Lake Chad region. This finding accords with other studies[250] showing that the locations of urban agglomerations remain persistent over time even after controlling for other factors that led to their establishments in the first place. These urban agglomerations continue to grow faster compared to more sparsely populated areas and have important implications for widening spatial gaps between those core cities and the rest of the countries.

248 Boko Haram conflict includes any violent incident where an actor includes: Islamic State (West Africa) and/or Boko Haram - Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad or Boko Haram - Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad.

249 Henderson et al. 2018.

250 See Henderson et al. 2018; Jedwab et al. 2017.

Market accessibility is positively correlated with the annual rate of economic growth and this relationship is statistically significant. Indeed, besides the initial level of nighttime light and population size, market access has one of the highest contributions to explaining variation in the annual rate of growth in nighttime lights, accounting for 6 percent of variation in the dependent variable. As discussed above, there remains a large number of people in the region who are left disconnected from other potential markets due to poor road networks and infrastructure in and around the Lake Chad region. To better enhance the natural and human potential of the Lake Chad region, better connectivity and mobility within the Lake Chad region and also between the region and other areas of the countries will improve the living conditions of the population and can lead to a catalytic effect where development benefits in other sectors, such as basic services and livelihoods, can be maximized.

Climate conditions play an integral role in determining local economic growth particularly in largely agricultural lands. The positive effect of favorable weather conditions during the growing seasons on local economies increases in more agrarian economies, as indicated by a statistically significant positive interaction term between average SPEI for 1992–2013 during the growing seasons and cropland density. These findings suggest that the impact of climate shocks is not spatially uniform and assessing the potential risks that erratic weather conditions may pose to local agricultural economies should be carefully evaluated.

Lastly, the incidence of Boko Haram conflicts is negatively correlated with local economic growth. More substantively, a one percentage point increase in the number of BH-related conflicts is associated with the slower annual rate of growth in nighttime lights by 0.4 percent. As discussed above, Boko Haram conflicts have been a major threat to local economies by disrupting regional trade and imposing immeasurable humanitarian costs. Our results seem to corroborate this. On the other hand, it is worth noting that non-BH conflicts are positively correlated with local economic growth.

2.5 Conclusion

The notes has presented an analysis of core development challenges that detail the Lake Chad region from the path of sustainable economic growth. The findings highlight the laggedness of the region compared to the rest of each respective country in multiple dimensions—including poverty, human capital outcomes, access to public services, among others.

The Lake Chad region is characterized by a combination of low density as well as high distance/division, which coalesces to present constraints to its regional growth. Due to a lack of vibrant agglomeration economies, the region fails to unleash scale economies that could spur job creation, improve access to core services, and generate new economic opportunities for the poor. Low density is further compounded by high distance that characterizes the economic geography of the region. Due to the poor quality of road infrastructure—in combination with the landlocked geography of the region and ongoing conflict—a large number of people in the region remain disconnected from large markets within their own respective country or in the neighboring countries. That said, simply investing in connective infrastructure does not necessarily yield expected economic benefits unless such investment is combined with complementary policies to mitigate the negative impact of high division rooted in pre-existing ethnolinguistic cleavages and ongoing conflicts.

Table 2.1: Main correlates with local economic growth: Regression analysis

Model	***(1)***	***(2)***	***(3)***	***(4)***
Sample	***Intensive margin***	***Full sample***	***Intensive margin Within Lake Chad***	***Full sample Within Lake Chad***
Nighttime light in 1992 (ln)	-0.010***	-0.006***	-0.007	-0.006
	(0.002)	(0.002)	(0.005)	(0.006)
Lake Chad region	0.000	-0.000		
	(0.010)	(0.001)		
Population in 1990 (ln)	0.003***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.001)	(0.000)
Annual growth rate of population (1990–2015)	0.083***	0.022***	0.116*	0.025
	(0.018)	(0.007)	(0.060)	(0.016)
Access to gridded electricity	0.003***	0.002***	0.005	0.002
	(0.001)	(0.000)	(0.004)	(0.001)
Market accessibility	0.002***	0.001***	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
SPEI in 1992	0.006	0.002**	-0.008	-0.000
	(0.005)	(0.001)	(0.016)	(0.001)
Cropland density in 1990	0.000	-0.000	-0.000**	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
SPEI in 1992 × Cropland density in 1990	-0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Avg. SPEI (1992-2013)	-0.019**	-0.003**	-0.002	-0.003
	(0.008)	(0.001)	(0.033)	(0.003)
Avg. SPEI (1992-2013) × Cropland density in 1990	0.001**	0.000**	0.000	0.000
	(0.000)	(0.000)	(0.001)	(0.000)
Number of BH conflicts (ln)	-0.004*	-0.003**	-0.001	-0.002**
	(0.002)	(0.001)	(0.001)	(0.001)
Number of non-BH conflicts (ln)	0.001	0.002**	0.003	0.005***
	(0.001)	(0.001)	(0.003)	(0.001)
Number of civilian protests/riots (ln)	0.003*	0.004**	-0.005	-0.006
	(0.002)	(0.002)	(0.005)	(0.004)
Grazing land density	0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Elevation	0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Terrain constraints	-0.001	-0.000	-0.003**	-0.000
	(0.001)	(0.000)	(0.001)	(0.000)
Observations	5,211	32,097	663	5,369
R-squared	0.393	0.317	0.254	0.097

Standard errors clustered by ADM1 regions. All the regressions include ADM1 regional dummies and fixed effects for major crops. Note that the intensive margin sample only includes cells that are ever lit at some point between 1992 and 2013 whereas the full sample includes all cells.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 2.2: Shapley decomposition on select indicators

Model	***Intensive margin***		***Full sample***		***Intensive margin Within Lake Chad***		***Full sample Within Lake Chad***	
Factor	***Shapley value***	***Percent***	***Shapley value***	***Percent***	***Shapley value***	***Percent***	***Shapley value***	***Percent***
Nighttime light in 1992 (ln)	0.14346	36.53	0.07396	23.33	0.00713	2.81	0.00201	2.07
Population in 1990 (ln)	0.04657	11.86	0.07722	24.36	0.02161	8.52	0.03775	38.88
Annual growth in population	0.00685	1.75	0.0054	1.70	0.01248	4.92	0.00671	6.91
Avg. SPEI (1992–2013)	0.01611	4.10	0.001	0.32	0.01827	7.21	0.00257	2.64
Avg. SPEI (1992–2013) X Cropland 1990	0.00636	1.62	0.00273	0.86	0.0192	7.57	0.00338	3.48
# of non-BH conflicts	0.00356	0.91	0.00721	2.28	0.00544	2.14	0.00654	6.74
# of BH conflicts	0.00103	0.26	0.00055	0.17	0.00519	2.05	0.00134	1.38
# of civilian protests/riots	0.0061	1.55	0.01012	3.19	0.00273	1.08	0.00207	2.13
Market access index (ln)	0.06337	16.14	0.0276	8.71	0.00901	3.55	0.00561	5.78
TOTAL	**0.39271**	**100.00**	**0.31696**	**100.00**	**0.25351**	**100.00**	**0.09709**	**100.00**

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Appendix 2.A: Supplementary Information

Table A2.1: Socioeconomic Outcomes in the Lake Chad Region and Other Regions

	Cameroon			Chad			Niger			Nigeria		
	National	*Rest of country*	*LCB*	*National*	*Rest of country*	*LCB*	*National*	*Rest of country*	*LCB*	*National*	*Rest of country*	*LCB*
Poverty and Human Capital (percent)												
Poverty	26.0	18.8	58.8	38.1	39.8	30.7	45.4	43.4	51.6	39.1	37.7	72.3
Literacy (15+)	77.8	83.7	47.1	41.6	45.5	21.0	33.0	32.8	34.0	71.9	72.4	58.7
Primary Completion (14–25)	72.3	79.0	39.4	29.5	32.8	12.2	25.4	27.8	17.4	78.2	79.0	60.0
Child stunting	28.9	26.9	37.3	39.9	37.0	51.0	43.9	41.7	52.2	36.8	35.8	48.0
Employment (percent)												
Agriculture	45.9	39.0	78.0	76.2	77.0	72.2	74.7	75.5	68.5	43.2	42.2	43.2
Industry	15.6	17.1	8.7	7.0	6.9	10.2	7.9	7.2	7.5	9.4	9.5	9.4
Service	31.0	35.3	10.9	13.6	12.8	17.0	15.6	15.2	20.4	37.1	37.7	37.1
Access to Public Services (percent)												
Piped Water	35.6	39.6	14.8	15.9	16.4	13.8	31.8	34.7	23.5	11.2	10.4	20.7
Improved Sanitation	61.1	66.9	30.8	14.1	16.2	5.7	24.8	28.5	14.3	56.3	56.4	55.1
Electricity	62.2	70.4	19.6	7.7	9.0	2.4	14.4	16.0	10.0	59.4	61.3	38.4

Source: World Bank calculations based on data of the national authorities.
Note: Data on education (literacy and primary education), and employment are based on the latest household surveys conducted in Cameroon (2014), Chad (2018), Niger (2018), and Nigeria (2018). Job category by industry includes only working-age individuals (ages 15–65). Data on poverty are based on the latest harmonized household surveys conducted in Cameroon (2014), Chad (2011), Niger (2014), and Nigeria (2018). Poverty rates are based on the US$1.90 international poverty line (2011 purchasing power parity). Data on child health (child stunting) and access to public services are drawn from the latest Demographic and Health Surveys available in each country: Cameroon (2018), Chad (2018), Niger (2012), and Nigeria (2018). Rest of country = outside the Lake Chad region; LCB = within the Lake Chad Basin region.

Appendix 2.B: Descriptive Statistics and Sources of Data Used in the Multivariate Regression

Variable	*N*	*mean*	*sd*	*min*	*max*
Annual rate of growth in NTL (1992–2013)	32097	0.001	0.01	-0.148	0.15
Nighttime light in 1992 (ln)	32097	0.063	0.372	0	4.156
Lake Chad dummy	32097	0.167	0.373	0	1
Population in 1990 (ln)	32097	1.387	1.386	0.693	9.299
Annual growth rate of population (1990–2015)	32097	0.011	0.022	-0.194	0.244
Access to gridded electricity	32097	0.211	0.408	0	1
Market accessibility	32097	8.062	4.87	0.889	31.963
SPEI in 1992	32097	0.32	0.463	-0.889	1.265
Cropland density in 1990	32097	11.566	16.59	0	68.939
Avg. SPEI 1992–2013	32097	-0.226	0.187	-0.688	0.422
Number of BH conflicts (ln)	32097	0.005	0.095	0	5.568
Number of non-BH conflicts (ln)	32097	0.03	0.223	0	5.333
Number of civilian protests/riots (ln)	32097	0.01	0.136	0	4.883
Grazing land density in 1992	32097	23.55	26.694	0	76.83
Elevation	32097	473.007	263.173	1.339	3015.201
Terrain constraints	32097	2.439	1.029	0	7

Appendix 2.C: Market Access Index

Definition

In this report, we define market access as a measure of accessibility from one origin to all destinations based on travel distance (or travel time). More formally, market access for a given location (or origin) i can be expressed as follows:

$$MA_{ot} = \sum_{d} P_{dt} \tau_{odt}^{-\theta}$$

where P_d refers to the population of a location (or destination) d, τ_{odt} is travel time from cell o to destination d, and θ is a trade elasticity or decay parameter measuring how trade volumes fall as travel times increase. We set θ at 3.8 following Jedwab and Storeygard (2020) Destinations that are considered in the construction of this index include all urban agglomerations with a population greater than 100,000.[251] In other words, market access is the weighted sum of population in all the destinations, which are weighted by travel time/distance. Travel time is computed based on the friction map generated by Weiss et al. (2015). In this study, destinations are defined as all major population centers in those four countries and origins are points on the road network that are closest to the centroid of each village.

Data

The calculation of market access requires the following information: 1) census population and geographical coordinates (e.g., longitude and latitude) of all population centers; and 2) road network data. Population centers are defined as those half-degree grids with more than 300,000 inhabitants. For road network information, we rely on *OpenStreetMap*.

251 We used grid-level population data (at a resolution of 1km) from the Global Human Settlements (GHS) to identify urban agglomerations. We first generated a boundary shapefile of urban agglomerations which correspond to all adjacent grid cells with a population size greater than 5,000. We then computed travel time from each grid cell to the centroid of those urban agglomerations.

Appendix 2.D: Rural Access Index

The Rural Access Index (RAI) measures the share of rural population living within 2km away from all-season roads. To construct this index, we rely on three sources of data: OpenStreetMap, WorldPop 2015 population estimates, and GRUMP Global Rural-Urban Mapping Project, Version 1 (GRUMPv1) (CIESIN, Columbia University, CUNY, CIDR, IFPRI, and CIAT 2017). We apply the following methodology as laid out in https://rai.azavea.com/:

- Select commonly used tags from OpenStreetMap (Trunk, Primary, Secondary, Tertiary) that serve as an approximation for all-season roads
- Create a mask based on 2 km buffer on these roads
- Create a mask based on urban areas as defined by GRUMP urban extents polygons
- Summarize the population remaining on the 100 metre raster dataset from WorldPop 2019

Technical Paper 2. Climate Change, Rural Livelihoods, and Urbanization: Evidence from the Permanent Shrinking of Lake Chad

Remi Jedwab (George Washington University), Federico Haslop (George Washington University), Takaaki Masaki (World Bank), and Carlos Rodríguez-Castelán (World Bank)

3.1 Introduction

There is a vast economic literature studying the effects of climate change on long-run growth, migration, urbanization and human capital, among several other outcomes. A sizable portion of this literature has been dedicated to the study of weather trends and shocks, and droughts in particular—an area of research of increasing importance in a world that is projected to become considerably drier by the end of the century (see C.-E. Park et al. 2018; S. Hsiang and Kopp 2018).

Nevertheless, very little attention has been paid in the literature to how aridification can impact livelihoods through the disappearance of lakes and other water resources. Lake Chad, once the second largest wetland in Africa (Hutchinson et al. 1992), lost about 90 percent of its surface water area—around 23,000 sq km—between the mid-1960s and the mid-1980s. This is equivalent to the total area of 4,200 American football stadiums, in just 20 years. Alternatively, 23,000 sq km is about 10 percent more than the total area of El Salvador, Israel or Slovenia. While its water level has been slightly recovering since the mid-1990s, it is still on average 80 percent less than in the mid-1960s. The resultant increasingly harsh environment, in the absence of climate change adaptation measures, has led to the development of self-serving political elites in northern Nigeria and furthered the eruption of the Boko Haram conflict (Onyia 2015).

It is all the more important to study this research question as lakes are important economic assets for various developing regions and countries of the world, such as the Caspian Sea in Eastern Europe, Central Asia, and Western Asia, or Lake Victoria, Lake Tanganyika, Lake Malawi, Lake Bangweulu and Lake Turkana in East Africa. Importantly, Africa has ten of the fifty largest lakes in the world.[252] Before shrinking, Lake Chad was the 11th largest lake in the world and the 4th largest lake in Africa. Other major examples of drying lakes include the Aral Sea (Kazakhstan and Uzbekistan), formerly the fourth largest lake in the world, and Lake Urmia (Iran), formerly the largest lake of the Middle East. Both shrunk to less than 10 percent of their former size. However, the reasons for their aridification differ. For Lake Chad, aridification came from long-term climate change. For the two other lakes, human actions were responsible. First, the Aral Sea dried up because its feeding rivers were diverted by Soviet irrigation projects. Second, Lake Urmia dried up because its feeding rivers were dammed. In contrast, as explained below, Lake Chad dried up for mostly geographical—and locally exogenous—reasons.

Understanding the local economic effects of drying lakes is not straightforward, as lake recessions can have ambiguous effects. On the one hand, a receding lake frees up arable land that can be used for farming. On the other hand, a receding lake can negatively impact fishing communities, farmers that rely on the lake's waters for their irrigation needs, and cattle herders who need the lake's waters and the vegetation around it so that their cattle can drink and eat enough. In poor and poorly connected countries, urban communities may also rely on the lake for transporting goods. Furthermore, as a lake keeps drying, the arable land that was originally freed up may also aridify. All these factors may result into intensified competition over limited resources, potentially feeding into conflicts. At the same time, in the longer run, residents of lake shore areas can potentially adopt adaptation strategies that help them mitigate the impact of lake recessions. The short and long run effects of lake recessions might thus differ.

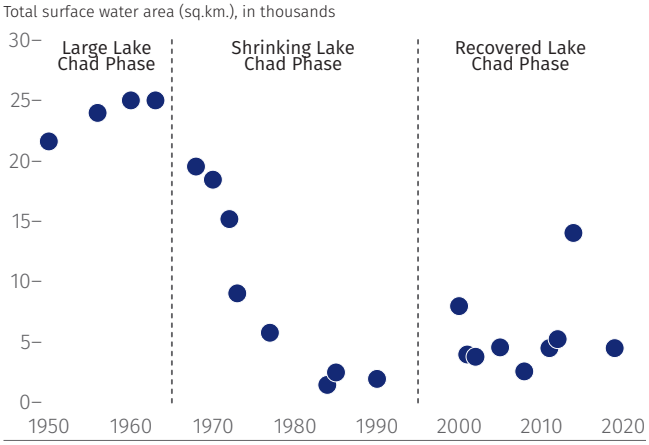
In this paper we analyze how the shrinking of Lake Chad affected local economic development—as proxied by local population growth in the absence of better

252 1Other large lakes are usually found in North America, Russia or Central Asia.

data—and urbanization—city population growth—in the already vulnerable sub-Saharan African region of the Sahel, trying to understand the economic consequences of a geographical phenomenon that may become more and more common as the world becomes drier and drier.

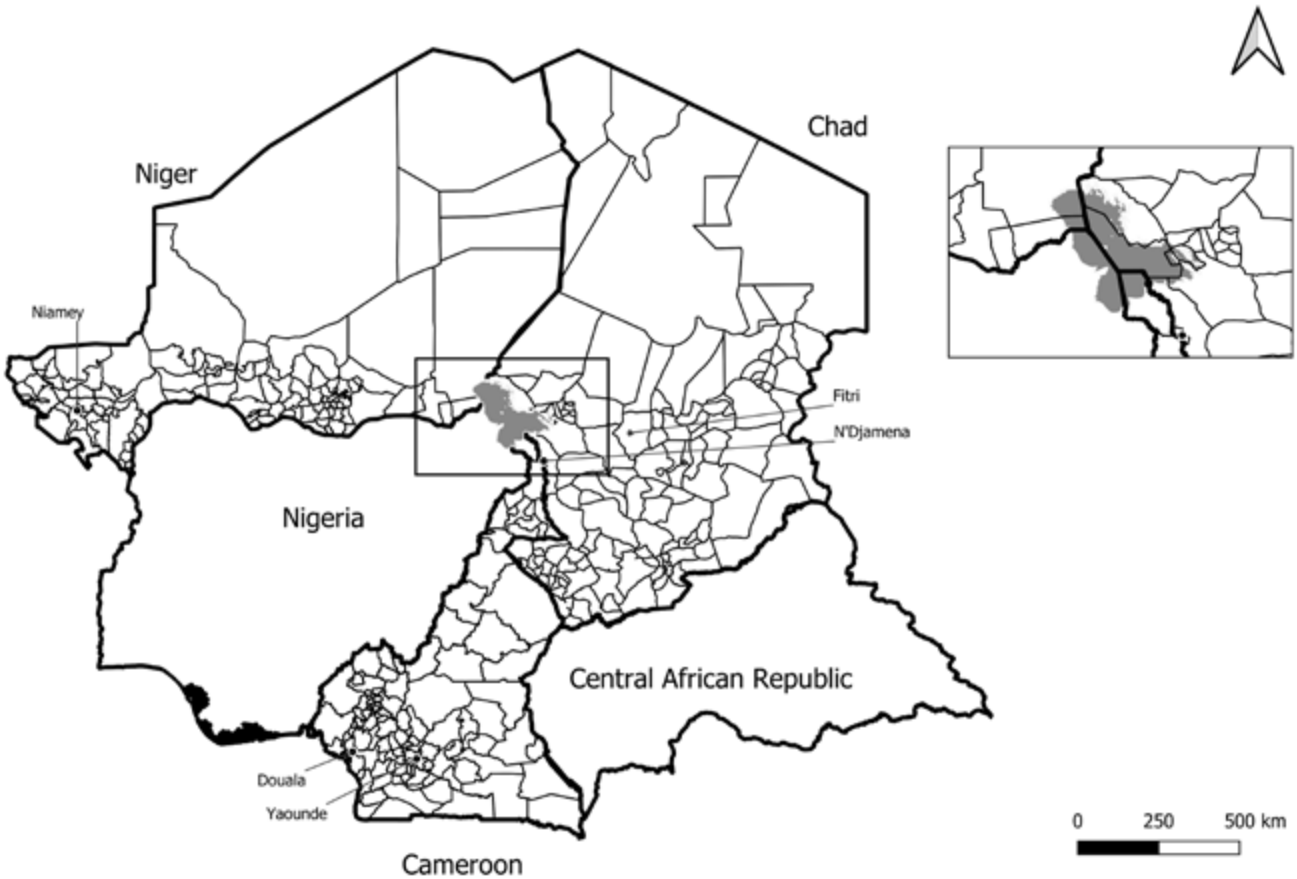
We focus our analysis on three low-income countries whose territory borders Lake Chad: Cameroon, Chad and Niger (see Map 3.1). In the three countries, the 1960s marked the beginning of a crisis for the lake. Figure 3.1 presents the evolution of the lake's total surface water area from 1950 to 2020, showing an enormous decrease in size between 1965 and 1985 and partial recovery after 1995. In our analysis, we thus divide the full period into three subperiods: pre-1965 (Large Lake Chad), 1965–1995 (Shrinking Lake Chad), and post-1995 (Recovering Lake Chad). Next, we treat the shrinkage of the lake as

Figure 3.1: Evolution of Lake Chad's Total Surface Water Area (sq km), 1950–2020



Notes: Total surface water area was obtained from the following sources: Olivry et al. 1996, Sédick n.d., FAO 2009, Comission du Bassin du Lac Tchad 2015, Okpara, Stringer, and Dougill 2016 and Ighobor 2019.

Map 3.1: Location of Lake Chad and Subdistrict Boundaries for the Three Countries of Study



Notes: This figure shows consistent reconstructed subdistrict boundaries for the three countries of study for the period circa 1950s–2010s. Cameroon, Chad and Niger are divided into 113, 138 and 119 subdistricts, respectively. Lake Chad is shown in the center of the map. We also show the location of the capital (and most populated city) of Niger (Niamey) and Chad (N'Djamena). For Cameroon, we show its capital city (Yaoundé) as well as its most populated city (Douala) today. Finally, we indicate the location of Lake Fitri (in Chad).

an "exogenous" shock, as the shrinkage was not driven by local economic or geographical conditions but reduced rainfall in a fourth country, the Central African Republic (CAR) (see Map 3.1), thus assuaging reverse causality concerns. Indeed, the Logone and Chari rivers flow from the CAR through Chad into Lake Chad. Once one controls for proximity to these rivers, the shrinkage of the lake could thus be considered "exogenous". Alternatively, one can focus on Niger, the country most distant from the CAR. As such, the shrinkage of Lake Chad offers a natural experiment that helps us examine how long- term lake drying can affect both rural and urban communities.

To conduct our analysis, we construct a novel data set tracking total population patterns at a fine spatial level—113, 138 and 119 subdistricts in Cameroon, Chad and Niger, respectively—and city population patterns—166, 179 and 100 cities in Cameroon, Chad and Niger, respectively—from the 1950s to the 2010s. We then use (relative) total population growth as our main outcome of interest, finding in a panel-difference-in-difference (DiD) framework for the three countries: (i) no differential effect of proximity to the lake before 1965 (Large Lake Chad period); (ii) a substantial negative effect of proximity to the lake in 1965–1995 (Shrinking Lake Chad period); and (iii) an effect that remains strongly negative post-1995, despite the slow recovery of the lake's water level (Recovering Lake Chad period). Our results suggest that fishing communities, farmers and cattle herders were negatively impacted by the lake receding. As incomes probably decreased in the area, households likely outmigrated to other areas.

In addition, we study how the shrinkage of the lake impacted nearby urban communities. Using the same panel-DiD framework but studying city population growth instead of total population growth, we find that city population sizes increased (however, not significantly so) or remained stable in the long run. Hence, it is suggested that (relative) rural population decline has been the main component of the (relative) total population decline observed in the area. Cities might then have acted as a safety valve sector for economic refugees from the Lake Chad area. We observe different population growth patterns for smaller (5K+) and larger (20K+) cities in the three countries, possibly due to different initial urban conditions. For example, in Niger, the disaster led to urban concentration in 20K+ cities. Finally, only in Niger did the government disproportionately build higher-quality roads towards Lake Chad. Yet, it does not appear that such investments mitigated the impact of the shock on the total population.

Our paper contributes to the literature on the socio-economic and demographic impact of climate change. Previous works have focused on the effects of rainfall or droughts on a wide range of development outcomes, such as migration (Gray and Mueller 2012; Rosenzweig and Udry 2014), urbanization (Barrios, Bertinelli, and Strobl 2006; Henderson, Storeygard, and Deichmann 2017), civil conflict (Harari and Ferrara 2018) and education (Maccini and D. Yang 2009; Shah and Steinberg 2017). Other studies have also examined how increases in temperature may drive rural-to-urban or within-country migration (Bohra-Mishra, Oppenheimer, and S. M. Hsiang 2014; Partridge, Feng, and Rembert 2017), international migration (Beine and Parsons 2015; Cattaneo and Peri 2016; Baez et al. 2017; Jessoe, Manning, and Taylor 2017; Peri and Sasahara 2019), conflict (Eberle, Rohner, and Thoenig 2020), agricultural output (Schlenker, Hanemann, and Anthony C. Fisher 2005; Schlenker, Hanemann, and Anthony C. Fisher 2006; Deschénes and Greenstone 2007; Anthony C Fisher et al. 2012; Burke and Emerick 2016; Aragón, Oteiza, and Rud 2021; S. Chen and Gong 2021; Steve Miller et al. 2021), economic growth (Dell, Jones, and Olken 2012), exports (Jones and Olken 2010; Kalemli-Özcan, Nikolsko–Rzhevskyy, and Kwak 2020), mortality (Deschénes and Moretti 2009; Deschénes and Greenstone 2011; Barreca et al. 2015), and birth weight (Deschénes, Greenstone, and Guryan 2009).[253]

253 See Tol 2009 and Dell, Jones, and Olken 2014 for a review of the literature on the impacts of climate change.

Our paper is also related to the literature on natural disasters and their impact on development. There is already a well-established body of literature on how natural disasters may affect various development outcomes, including international migration (Mahajan and D. Yang 2020; Spitzer, Tortorici, and Zimran 2020; Beine and Parsons 2015), domestic migration (J. J. Chen et al. 2017; see Gröger and Zylberberg 2016 for Vietnam; Bohra-Mishra, Oppenheimer, and S. M. Hsiang 2014, Kirchberger 2017, and Kleemans and Magruder 2017 for Indonesia; and Boustan, Kahn, and Rhode 2012 for the US), human capital outcomes (G. Caruso and Sebastian Miller 2015; G. D. Caruso 2017) and urban activity (Gallagher and Hartley 2017; Brooks and Donovan 2020; Kocornik-Mina et al. 2020) among others.

What sets our work apart from these existing studies on the socio-economic impact of climate change or natural disasters is that we study the shrinkage of a lake as another important natural disaster shock that explains long-term urbanization patterns in its neighboring regions. Lake disappearances are interesting, and important, cases to study in and of themselves. Most existing studies have examined the effects of climate change by investigating the local economic effects of weather-related shocks, in particular rainfall, temperature and humidity shocks. While weather-related shocks are most often locally exogenous, they are often *temporary* shocks. It is much more difficult to find cases of *permanent* shocks, such as a lake almost entirely drying over a period of 20 years. To some extent, our shock resembles much more the main object of such studies, i.e. climate change, a *permanent* change in climate conditions. In addition, unlike existing studies on coastal flooding, which typically leads to crop losses and/or destruction in cities, we study the effects of lake recessions. Lake recessions have in theory more ambiguous effects, because some valuable land may become newly available.

The findings of our paper are also relevant to understanding the economic effects of natural resources. The literature has shown that the presence—or discovery—of natural resources can be a blessing (Aragón and Rud 2013; Arezki, Ramey, and Sheng 2016; Allcott and Keniston 2017) or a curse for development (Torvik 2002; Ploeg 2011; Venables 2016, Armand et al. 2020) depending on local contexts. Natural resources can also be a source of conflict and instability (Berman et al. 2017), even destabilizing the security situation of neighboring regions (Caselli, Morelli, and Rohner 2015; Adhvaryu et al. 2021). Our study sheds a new light on the nexus between natural resources (or lack thereof) and development by studying how the withdrawal of water resources due to lake shrinkage may disrupt local economies in areas near the lake and thereby hamper urban growth.

Finally, we focus our analysis on three countries that are among the poorest in the world. Understanding the effects of climate change and natural disasters in such contexts is particularly important. Chad and Niger are then two Sahelian countries and are as such likely to be very negatively impacted by climate change in the future, hence the need for more research on the effects of "past" climate change events on their economies and societies.[254]

The paper is structured as follows: Section 3.2 dives into some of the physical characteristics of Lake Chad and its water sources. Section 3.3 introduces our novel data. Section 3.4 presents the hypothesis and empirical strategy behind our analysis. Sections 3.5, 3.6 and 3.7 present results on total population, cities and roads, respectively. Finally, section 3.8 concludes.

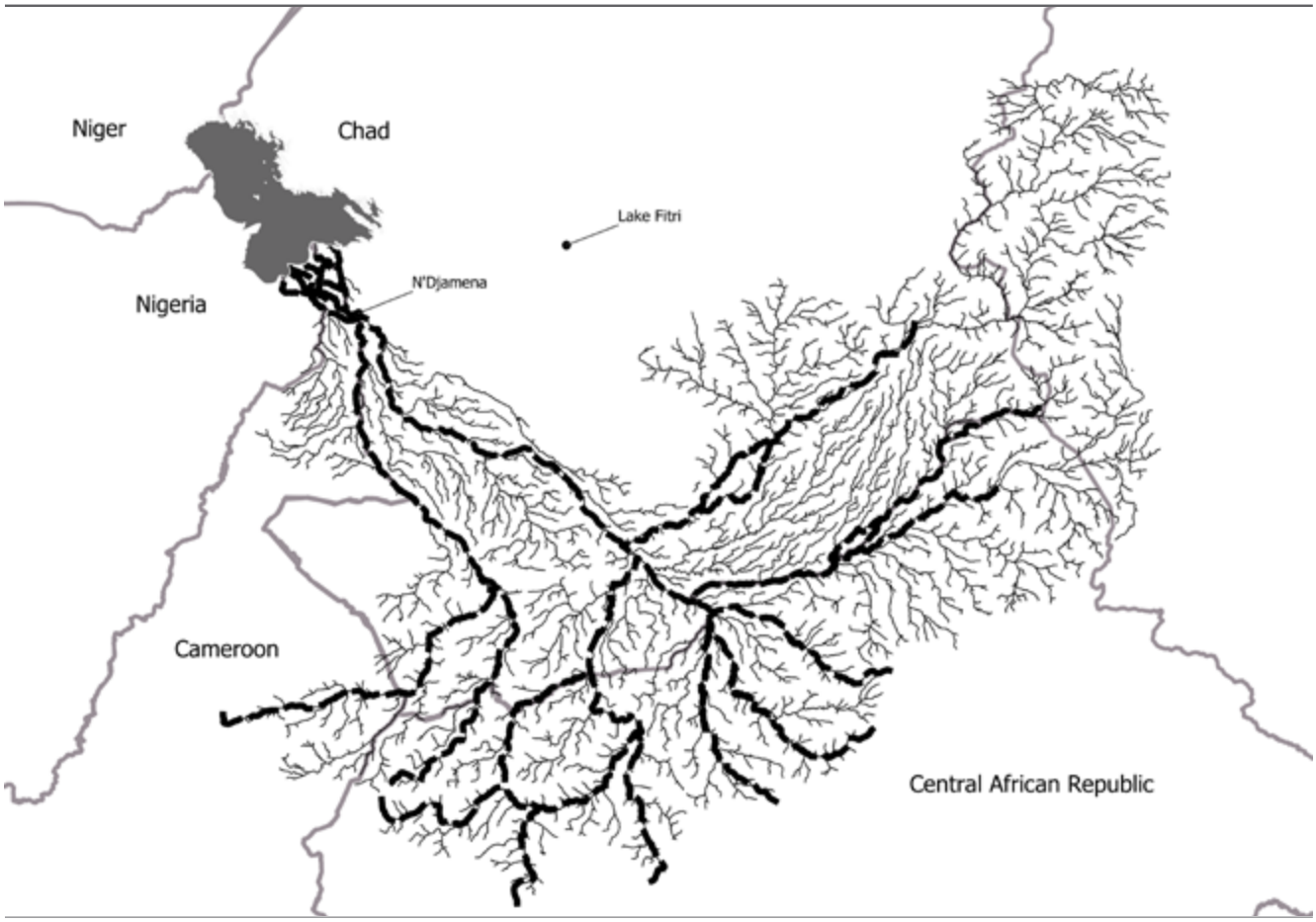
254 The only few studies regarding the local effects of a smaller Lake Chad are (non-economics) articles that rely on contemporary small-sample village surveys to provide very detailed, but also very local, analyses of the situation (see, for example, Sarch and Charon Birkett 2000; Okpara, Stringer, and Dougill 2016, Luxereau, Genthon, and Karimou 2012). Despite the importance of these studies to understand how a smaller lake has affected households in the area, these analyses have many shortcomings that our paper addresses (despite the limitations of our own analysis). To the best of our knowledge, this is the first (economics) paper that identifies the short and long-term causal effects of a shrinking lake on local economic development, both in rural and urban settings.

3.2 Background: The Lake Chad and Its Tributaries

About 90 percent of Lake Chad's water comes from the Chari-Logone river system (see Map 3.2). The river system then primarily originates from rainfall in the mountainous areas of the Central African Republic (CAR) (Hutchinson et al. 1992). Rainfall in the Adamawa Highlands of Cameroon also somewhat contribute to the system. Because the water inflow of the lake depends almost exclusively on the Logone-Chari system, lack of rainfall over the CAR was by far the main reason behind the large drop in water area observed after 1965 (Figure 3.1).

The fact that the Lake's water level is primarily determined by rainfall in another country south of our region of study provides reassurance that the results will not be explained by reverse causality. Nonetheless, this does not rule out other potential sources of bias. Because the Logone-Chari river system goes through the territory of Cameroon and Chad, outcomes in the Lake's surroundings may not be independent of outcomes upriver. Indeed, the same shock that affected the lake's residents—dryer rivers due to lower rainfall in CAR—may have also affected other households along the river

Map 3.2: Major and Minor Rivers of the Chari-Logone River System Feeding Lake Chad



Notes: The Chari River and its tributary, the Logone, provide almost all of Lake Chad's water. The Chari River flows from the Central African Republic (shown in the map) through Chad into Lake Chad. We show in bold the main rivers of the Logone-Chari system (Shapefiles obtained from the Landscape Portal). In grey, we show other streams associated with the Logone-Chari system (Shapefiles obtained from FAO/GeoNetwork). We also show Lake Fitri.

system. In that case, and in the case of Chad in particular, areas farther away from the Lake are also directly affected. If the Lake areas—i.e., the "more treated" group—and the river areas—i.e., the "less treated" group—are similarly affected—either positively or negatively—then the magnitude of the estimated effect will likely be underestimated.

For these reasons, we will control for proximity to the Logone-Chari river system. In addition, the fact that the river system is not present in Niger implies that this country presents the "cleanest" environment to test our hypothesis, as the shock was more "exogenous" there than anywhere else. Furthermore, because the Logone-Chari system occupies a smaller share of Cameroon's territory than Chad's territory, Cameroon provides a more "exogenous" setting than Chad. However, we will find relatively similar results for the three countries, at least when studying total population levels. This gives us confidence that we are effectively controlling for any potential bias generated by the river system. This also ensures that we are not picking up an effect due to country-specific institutions or spatial policies. Finally, this reinforces the external validity of our results, especially considering that Cameroon is wealthier than Chad and Niger.

Another characteristic of Lake Chad that must be considered is the heterogeneous degrees of dryness that were experienced over its different regions. Cutting Lake Chad in half lies what is called the *Grande Barrie`re*, an elevated area that in dry years divides the lake in a southern pool and a northern pool. Because the majority of the lake's water enters through the south (via the Logone-Chari river system), it is only when the water level of the southern pool is high enough that water crosses the Grande Barrie`re to replenish the northern pool. During the Large Lake Chad era (pre-1965), this geological feature remained submerged, rendering it irrelevant. However, as the Logone-Chari river's discharge rate declined, the Grande Barrie`re created a northern sink that dried almost completely in the 1980s (Okpara, Stringer, and Dougill 2016), and a southern sink that, although smaller in size, always retained an area of open water (CM Birkett 2000). We will exploit this fact when studying the effects for Chad, the only country where the two pools are present, thus expecting stronger effects for the northern pool.

3.3 Data for the Reduced-Form Analyses

For our analysis, we use subdistrict- and district-level data for Cameroon, Chad and Niger, some of the poorest countries in the world. Unfortunately, data availability is extremely scarce. However, any analysis of the impact of the lake shrinking demands localized data for the period 1965–1995 (shrinking Lake Chad phase) and the pre-1965 period (large Lake Chad phase). Due to this, total and urban population figures are the best (and only) measures available.[255]

3.3.1 Total Population Levels for the Subdistrict Samples

Few population censuses took place in the three countries and when population data is available, it is not at a fine spatial level like say counties in the U.S. Typically, the sources that we were able to get ahold of report population data at the regional or district level, and sometimes at the "subdistrict" level. However, subdistrict boundaries are rarely consistent across years. As such, we had to reaggregate subdistricts in order to reconstruct a set of consistently defined subdistricts over periods spanning more than 50 years. Overall, our reconstructed subdistrict dataset contains 119 units for Niger (1951–2012), 113 for Cameroon (1963–2005), and 138 for Chad (1948–2009). These subdistricts correspond to third-level administrative units, in particular *arrondissements* in Cameroon, *sous-prefectures* in Chad and *communes* in Niger. More details on the sources and the assumptions made can be found in the Web Data Appendix.[256] In the case of Niger, we have total population data for the years 1951, 1956, 1959, 1962, 1969, 1988, 2001, 2012, 2013 and 2017. Data for the years 1951, 1956, 1959, 1962, 1969, 2013 and 2017 come from administrative sources (often administrative censuses). Values for the years 1988, 2001 and 2012 come from the population censuses that took place those years.[257]

The Cameroon dataset includes the years 1963, 1967, 1976, 1987 and 2005. Information for 1963 and 1967 comes from administrative sources. Population figures for the years 1976, 1987 and 2005 are based on population census counts. Unfortunately, no census has taken place since 2005. For example, the 2018 population census was postponed indefinitely.

The Chad dataset includes the years 1948, 1953, 1965, 1993 and 2009. Population measures for the years 1948, 1953 and 1965 are based on administrative sources. For the year "1965", we use information from the 1962 administrative census and 1964 demographic survey as our baseline. When needed, we adjust the population levels that we obtain using information from the 1968 administrative census. We call this year "1965" because 1965 is the mid-year between 1962 and 1968. Lastly, we use census population figures for the years 1993 and 2009. Next, we excluded Nigeria from our analysis due to a long history of disputed census results. In fact, the 1962 and 1973 results were never officially validated and published due to various controversies surrounding their reliability and accusations of political manipulation (Ahonsi 1988).

Finally, Map 3.1 shows the boundaries of the reconstructed subdistricts. As seen, subdistricts are of a similar size across the three countries. Mean area is 9.1, 10.6 and 4.2 thousand sq km in Cameroon, Chad and Niger, respectively. In comparison, the mean U.S. county is 2.8 sq km.

255 The *Demographic and Health Surveys* of USAID and national household or labor force surveys are typically not available before the 1990s. Likewise, only the 1976, 1987 and 2005 population censuses of Cameroon are available on the website of IPUMS International. By 1976, the lake's level was already quite low. We are thus missing a year of data before the lake started shrinking. Finally, nighttime lights are only available from the year 1992.

256 The name of the third-level administrative units is also not constant over time in each country. The names referred here are the ones used by each country in the reports of their latest population census.

257 Administrative censuses are population counts that rely on official registers and other national and local files.

3.3.2 District Samples

In the case of Cameroon, we only have subdistrict population data for one year (1963) before the lake started shrinking. As such, we cannot investigate whether the parallel trends assumption holds for Cameroon. As a solution, we verify that it holds if we use instead total population data at the district level. More precisely, we reaggregate the 113 Cameroonian subdistricts into 47 districts, which allows us to add one year of pre-1965 data (1956; source = administrative census). Next, in our econometric analysis we will also include district-specific linear trends.

While we use the same 47 districts for Cameroon, we use 31 districts for Niger and 36 districts for Chad. Note that the distribution of districts does not reflect the distribution of districts in any particular year. Indeed, for district boundaries and subdistrict boundaries to be consistent, and in order to also preserve consistency over time, some aggregations had to be made. However, our boundaries more or less correspond to district boundaries in the 1960s.[258]

3.3.3 City Population Sizes

To study urbanization, we need a consistent definition of cities across the three countries and for all years available. As in many studies in the urban literature, we define as a city any locality with at least 5,000 inhabitants. We thus focus our data compiling efforts on localities that reached the threshold of 5,000 inhabitants at any point during our period of study.

For Niger, 166 localities reached 5,000 inhabitants at least once in 1900–2012.[259] For the pre-1968 period, we rely on colonial and post-colonial administrative reports of city population sizes (Niger became independent in 1960). Post-1968, we rely on reports of the population census (1977, 1988, 2001, 2012). Next, while we know the population size of almost all cities and for almost all years in 1977–2012, information for the years 1900–1968 is more patchy. In particular, when Niger was still a colony as well as in the early years of the post-independence period, no census was conducted. Instead, administrators would sequentially visit various regions of the country to proceed with administrative population counts, as in 1955–1962 and 1965–1968. As such, for 16 localities that already had more than 5,000 inhabitants before 1968, population is typically available for different years for different cities. To create a consistent population series for the pre-1968 period, we use exponential interpolations.

There are then a few cities for which we know their population before the 1940s and in the late 1950s but not in-between. In order to better predict their population circa 1950 (we indeed focus on the post-1950 period in our analysis), we also consider their pre-1950 population.

Next, for later years, there are a few cities for which the first population estimate available exceeds 5,000 by several thousands. As a result, these cities might have exceeded 5,000 in the previous years of data as well but we cannot be sure. To allow for this possibility, and for each city without any early population estimate, we assume that their 1945 population one inhabitant and then use exponential interpolation to fill the missing years. As such, this increases the likelihood that a city exceeds 5,000 if its value is well above 5,000 the following year of data.

Overall, for city-years where the obtained population is not above 5,000, we are confident based on our analysis that population is indeed below that number.

258 Districts correspond to *departements* or *prefectures* in the three countries

259 In particular, we have city population estimates for the following years: 1900, 1905, 1910, 1921, 1926, 1931, 1934, 1936, 1945, 1948, 1951, 1955–1962, 1965–1968, 1977, 1988, 2001, and 2012.

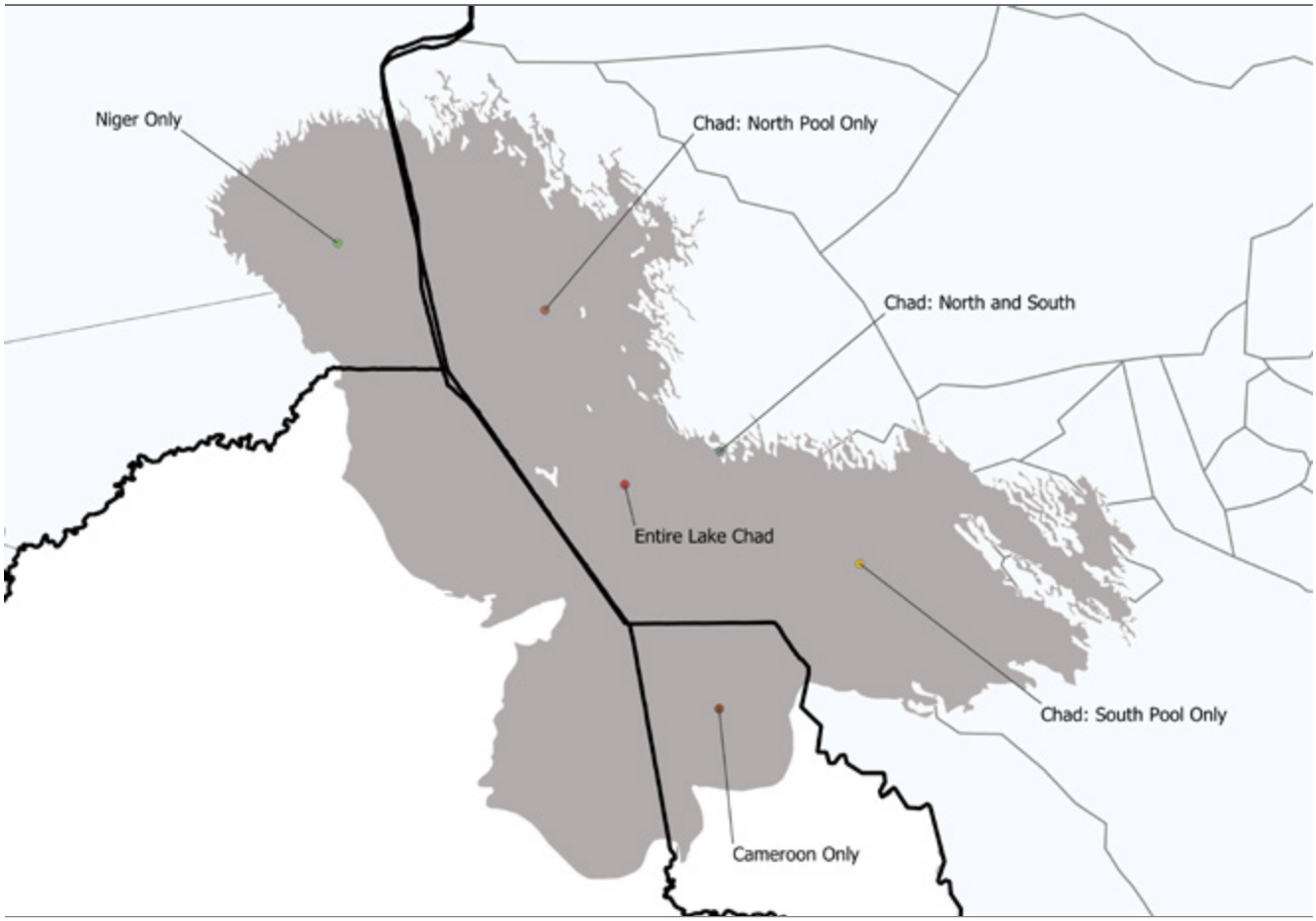
Our methodological choices should also not affect the results as few city-years are ultimately concerned.[260]

We then proceed similarly for both Cameroon and Chad. For Cameroon, 186 localities reached 5,000 at any point in 1932–2005.[261] For the pre-1976 years, we use colonial and post- colonial administrative counts (Cameroon became independent in 1960–1961). For the years 1976, 1987 and 2005, we use reports of the population census. For Chad, 100 localities reached 5,000 at any point in the period 1937–2009.[262] For the pre-1968 years, we use colonial and post-colonial administrative counts (Chad became independent in 1960). For the years 1993 and 2009, we use reports of the population census. For the years 1975 and 2000, we use administrative population count estimates provided by Chad's *Institute of Statistics*.

3.3.4 Geographical Proximity to Lake Chad

We obtain from the RCMRD Geoportal of the World Bank a shapefile of the full (pre-shrinking) Lake Chad

Map 3.3: Location of the Selected Country-Specific Centroids of Lake Chad



Notes: This figure shows the centroids of Lake Chad considered for each country.

260 For a limited sample of the cities, we know their exact population when it is below 5,000. However, we do not make use of that information due to possible endogenous selection issues in why an estimate is available or not.

261 The data set covers the years 1932, 1939, 1941, 1945, 1950, 1953, 1956, 1958-1968, 1970, 1976, 1987, and 2005.

262 The data set covers the years 1937, 1939–1951, 1954–1956, 1961, 1964, 1968, 1975, 1993, 2000, and 2009.

area. We then construct for each subdistrict/district centroid the Euclidean distance to various "centroids" in the Lake Chad polygon. In Niger, residents only have access to the northern pool of the Lake. Thus, the centroid that we consider is the centroid of the section of the northern pool that is within the territory of Niger (see Map 3.3). In Cameroon, residents only have access to the southern pool of the Lake. Thus, the centroid that we consider is the centroid of the section of the southern pool that is within the territory of Cameroon (ibid.). In Chad, residents have access to both pools. We thus consider: (i) The centroid of the section of the northern pool that is within Chad's territory; (ii) The centroid of the section of the southern pool that is within Chad; and (iii) The centroid of the section of the full Lake Chad area that is within Chad. Next, we also consider the centroid of the full Lake Chad area, thus abstracting from country boundaries. Finally, our main measure of proximity to Lake Chad is the negative of the logged Euclidean distances from these centroids to the subdistrict/district centroids.

3.4 Main Hypothesis and Specification

3.4.1 Main Hypothesis

The historical drop in water levels starting circa 1965 and the relative recovery of the lake after 1995 allow us to examine how the shrinking of a lake affects nearby communities. To do so, we exploit a simple difference-in-difference framework and study the effect of proximity to the lake on total population patterns. In particular, we expect proximity to the lake to have no effect on (relative) population growth before the shock (pre-1965) and possibly some effects during the main shock period (1965–1995) and the slow recovery period (post-1995).

A priori, the effects of a lake shrinking on nearby populations can be ambiguous. On the one hand, the shrinking of Lake Chad made available arable land that was unclaimed before, allowing villagers to switch at least part of their activities from fishing to farming (Sarch and Charon Birkett 2000). However, this coping strategy may have not been made available to all villages. Furthermore, as the lake kept shrinking, land that became available in the early years of the lake shrinking became farther and farther away from the lake shore, which increasingly limited irrigation possibilities. A smaller lake also reduces incomes in fishing communities. It can also impact cattle herding, an important sector in the Lake Chad region (herders typically sell their cattle to urban markets in Nigeria). Indeed, herders require the lake's water and the vegetation that grows around it. Finally, conflict within and between villages may also be a negative consequence of a smaller lake: as the lake dried and people moved closer to its shores, increased competition for resources could have led to social conflict (Okpara, Stringer, and Dougill 2016). The fact that four different countries share ownership over portions of the lake makes things even more complicated. As put by a local fisherman: "It's difficult to determine boundaries on water, yet the gendarmes [from Cameroon and Chad] always come after us and seize our fishing nets and traps and we have to pay heavily to get them back." (Murray 2007).

3.4.2. Baseline Specification

For subdistricts *s* and years *t* and each country at a time, we estimate the following model:

$$ln(Total\ Pop.)_{s,t} = \alpha + \sum_{v} \beta_v \times Prox.\ Lake_s \times I_{v=t} + \lambda_s + \theta_t + D_s \times t + X_s B_{s,t} + \mu_{d,t} \quad (1)$$

where $ln(Total\ Pop.)_{s,t}$ is the log of total population in subdistrict s in year t and our variables of interest are the interactions between the (time-invariant) measure of proximity to the lake and year dummies (we omit the first year of data so the effect is estimated relative to it). We add subdistrict (λ_s) and year (θ_t) fixed effects, as well as district-specific linear trends ($D_s \times t$) to control for local patterns of economic development at the district level over time. To account for spatial auto-correlation, we use Conley standard errors (distance cut-off of 100 km).[263]

Furthermore, our specification includes several time-invariant controls ($X_s B_{s,t}$) that we interact with year effects to flexibly allow them to have a different effect over time. We first add the logged Euclidean distances to the largest city as well as the capital city and their square.[264] Doing this allows us to flexibly control for spatial patterns of economic development that may be related to economic or political centralization (or decentralization). This is important in the case of Chad, as N'Djamena, its capital and largest city, is near the Lake Chad area.

263 With few years of data pre-shrinking, subdistrict-specific linear trends ask too much of the data.
264 The largest city (Douala) is indeed not the capital city (Yaoundé) in Cameroon.

For historical reasons, northern areas are less developed, and have been growing slower, than southern areas in the three countries. Geographical differences are also correlated with latitude, with declining vegetation density as one moves north and, in the case of Chad and Niger, desertification in the Sahel and Sahara zones. To control for this North-South gradient, we include the latitude of the subdistrict's centroid which we interact with year fixed effects.

We add two dummies for whether the subdistrict is crossed by a river of the main Logone- Chari river system or a river of the extended Logone-Chari river system, which we both interact with year fixed effects. Doing so controls for local effects of changes in the discharge rate of the Logone-Chari river system. As discussed previously, decreases in the discharge rate that eventually led to the shrinking of Lake Chad might have also led to differential patterns of development along the streams of the river system, in both Cameroon and Chad. The river flow may be associated with local economic development via changes in vegetation or irrigation.

Finally, classical measurement error in the dependent variable, for example due to issues with the reporting of population levels in the original sources and/or the reaggregation process that we submit the underlying data to, should only affect standard errors. If anything, precision should be reduced, especially for earlier years where population data might be less reliable.

3.5 Reduced-Form Effects on Total Population

We first study the effects of Lake Chad shrinking on subdistrict total population. As seen in Figure 3.1, the lake's water level dramatically dropped between 1965 and 1985. While residents might have initially expected the "shock" to be temporary, it became clear over time that the shock was permanent. Residents' economic and migratory responses to the aridification of the lake may have thus evolved over time. Effects observed in the later period then capture the realization that the shock was permanent but also adaptation strategies that households may have adopted. In addition, post-1995, the lake started recovering, albeit slowly (and erratically). Next, we assume that (relative) population growth is a good proxy for (relative) economic growth patterns. Within a same country, and abstracting from worker heterogeneity, the spatial equilibrium hypothesis implies that spatial population growth patterns are mainly explained by differential evolutions of nominal wages, prices and quality-of-life amenities (Topel 1986, Gollin, Kirchberger, and Lagakos 2017 and Chauvin et al. 2017). However, at (very) low income levels as in our context, amenities not directly related to prolonging life expectancy should matter little (Duranton 2016, Chauvin et al. 2017 and Jedwab and Vollrath 2019). Thus, by measuring population growth patterns, we should be capturing mainly an effect on real wages. In other words, a (relative) population increase in one location should indicate (relative) real wage growth. Population is then the most reliable measure to capture economic growth (or decline) around Lake Chad, as consistent information on real wages or employment at a fine spatial level does not exist in our context for most of the period of study.

3.5.1 Effects on Total Population for Niger, 1951–2017

Niger possibly offers the best environment for our analysis. Its territory does not contain any river belonging to the Logone-Chari system and we have more years of data, especially pre-1965. More precisely, we have 119 subdistricts x 17 years = 2,023 observations.

Table 3.1 presents the results. In col. (1), Lake proximity is defined using the centroid of the section of the northern pool that is contained with Niger's territory. We see no effect in 1956–1962 (the omitted year is 1951), suggesting parallel trends. In 1969, we see a large negative effect of -0.31**. Relative to the year 1962, the last year of available data before 1965, this effect is -0.23**. This implies that halving the distance from the lake is associated with a 23 percent relative decline in population. By then, the full Lake Chad, not just its area contained within Niger, had shrunk by about 22 percent. This effects becomes even more negative in 1988, at -0.41*** relative to the year 1962, implying that halving the distance from the Lake is associated with a 41 percent relative decline in population. The Lake water levels had then collapsed by 91 percent. Furthermore, in terms of standardized effects, a one standard deviation in proximity to the lake is associated with a 0.27 and 0.48 standard deviation decrease in log population by 1969 and 1988, respectively.

The effects remain negative after 1995. However, one should be cautions when interpreting the effects after 2009, since that year marks the start of the Boko Haram insurrection in Northeastern Nigeria. This could have affected local development. However, Blankespoor et al. 2020 show that Boko Haram had an impact on night lights in 2009–2012 but did not affect population levels by 2012. In addition, our 2001 and 2012 estimates are similar, suggesting a lack of population recovery after the lake regained some of its past water levels. In the post-1995 period and relative to the year 1962, the relative decrease in population was about 36 percent. In the same period, Lake Chad's level was still, on average, about 20 percent of its pre-1965 level.

Table 3.1: Effect of Proximity to the Lake, Total Population, Niger 1950s–2010s

Dependent Variable: Log Subdistrict Population in Year *t*

Lake Centroid: Omitted Year = 1951	***North NER (1)***	***Full Lake (2)***		***North NER (1) Cont'd.***	***Full Lake (2) Cont'd.***
Proximity to Lake (log) 1956	-0.01 [0.03]	-0.02 [0.04]	Proximity to Lake (log) 2012	-0.41* [0.24]	-0.64* [0.36]
Proximity to Lake (log) 1957	-0.05 [0.04]	-0.07 [0.05]	Proximity to Lake (log) 2013	-0.41* [0.24]	-0.65* [0.36]
Proximity to Lake (log) 1958	-0.06 [0.04]	-0.09 [0.06]	Proximity to Lake (log) 2014	-0.42* [0.24]	-0.66* [0.37]
Proximity to Lake (log) 1959	-0.07 [0.05]	-0.11 [0.07]	Proximity to Lake (log) 2015	-0.42* [0.25]	-0.67* [0.37]
Proximity to Lake (log) 1960	-0.08 [0.06]	-0.12 [0.08]	Proximity to Lake (log) 2016	-0.43* [0.25]	-0.68* [0.38]
Proximity to Lake (log) 1961	-0.08 [0.06]	-0.13 [0.09]	Proximity to Lake (log) 2017	-0.44* [0.25]	-0.69* [0.38]
Proximity to Lake (log) 1962	-0.08 [0.07]	-0.13 [0.09]	$\beta_{31969}-\beta_{31962}$	-0.23** [0.09]	-0.29** [0.14]
Proximity to Lake (log) 1969	-0.31** [0.13]	-0.42** [0.19]	$\beta_{31988}-\beta_{31962}$	-0.41*** [0.11]	-0.59*** [0.17]
Proximity to Lake (log) 1988	-0.49*** [0.15]	-0.72*** [0.22]	$\beta_{32017}-\beta_{31962}$	-0.36* [0.21]	-0.56* [0.32]
Proximity to Lake (log) 2001	-0.40** [0.20]	-0.61** [0.30]	Subdistrict (119) FE, Year (17) FE	Y	Y
			District (31) Trends; Controls	Y	Y

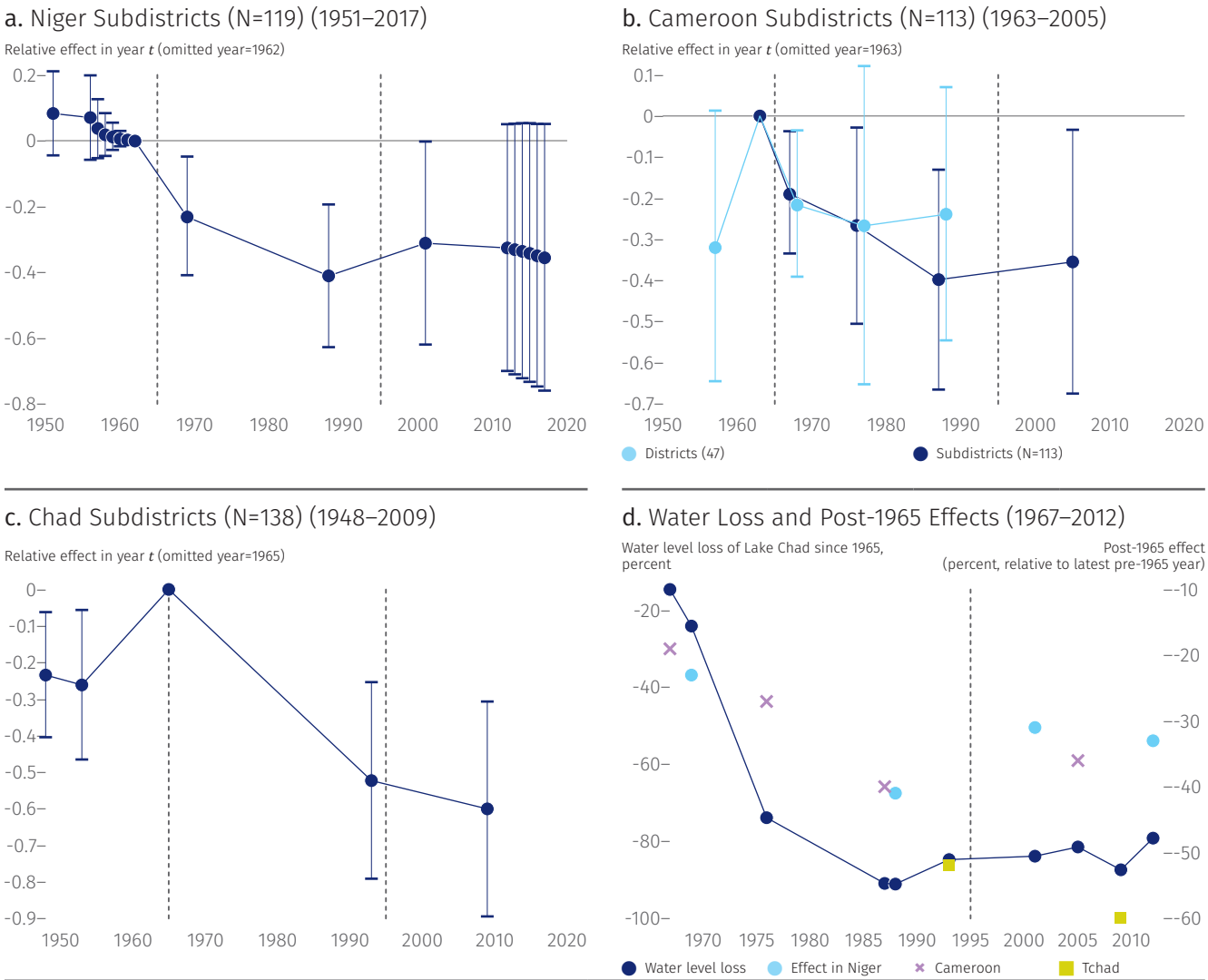
Notes: 119 subdistricts x 17 years = 2,023 obs. "North NER" is the centroid of the Northern section of Lake Chad that is within the territory of Niger (NER). "Full Lake" is the centroid of the full Lake Chad area. Conley SEs (100 Km).

Next, Figure 3.2a shows the effects when omitting 1962 instead of 1951 (95 percent confidence intervals are also reported). As seen, while the effects are strong in the sense that their magnitude is high, standard errors are high as well. If anything and relative to the point estimates, the standard errors increase in the later period when population censuses became more, not less, reliable. As such, the wide confidence intervals in the shrinking and post-shrinking periods imply that the observed average effects hide heterogeneous effects across subdistricts. If we study the effects in 1988, the average effect is about -40 percent and the corresponding lower-bound and upper-bound effects are about -20 percent and -60 percent respectively. This will led us to investigate subdistrict-specific factors that may have driven the heterogeneity in the effects.

Finally, in col. (2), we show the effects when proximity to the Lake is calculated using the Euclidean distance to the centroid of the whole Lake Chad area, not just the area within Niger. If anything, the effects are now stronger.[265] Because the "Full Lake" centroid is located more southern than the Niger-specific centroid, it gives more weight to subdistricts at the border with Nigeria. One possibility is that the shrinkage of Lake Chad also had negative effects in Northeastern Nigeria (before Boko Haram), which then impacted subdistricts in Niger.

265 In terms of standardized effects, a one standard deviation in proximity to the lake is associated with a 0.50 and 0.85 standard deviation decrease in log population by 1969 and 1988, respectively (vs. 0.37 and 0.58 in col. (1)).

Figure 3.2: Total Population Effect of Proximity to the Lake Chad, 1940s–2010s



Notes: Subfigures (a)-(c) show for vairous samples the effects of proximity to Lake Chad (relative to the omitted year shown at left). For subfigures (a), (b) and (c), the specifications are similar to Table 1 col. (1), Table 2 col. (1) and Table 2 col. (3), and Table 3 col. (1), respectively. However, the omitted year is the latest year available before 1965 (incl.) instead of the first year available as in the tables. The dashed vertical lines show the years the lake started to decline (c. 1965) and recover (c. 1995). We report 95 percent confidence intervals. Conley SEs (100 Km). In subfigure (d), we plot the estimated water level loss (percent) of Lake Chad relative to the year 1965 and the estimated post-1965 effects (percent) for the three countries in 1967–2012 (relative to the latest year available in each country).

3.5.2 Effects on Total Population for Cameroon, 1963–2005

For Cameroon, we have 113 subdistricts x 5 years = 565 observations. The results are presented in Table 3.2. The effects are estimated relative to the omitted year (1963). Unfortunately, the second year of data is 1967. We have thus only one pre-shock year and cannot examine parallel trends.

In Col. (1), lake proximity is defined with respect to the centroid of the section of the southern pool that is contained within Cameroon's territory. In 1967, we observe a negative effect of -0.19**, implying that halving the distance from the lake is associated with a 19 percent relative decline in population. By then, the lake had shrunk by 22 percent. In 1976, the effect is -0.27**, and the lake had shrunk by 77 percent. In 1987, when the Lake's size had collapsed to about 10 percent of its pre-drought size, the effect is -0.40***. Alternatively, a one

Table 3.2: Effect of Proximity to the Lake, Total Population, Cameroon 1960s–2010s

Dependent Variable: (1)–(2): Log Subdistrict Population in Year *t*; (3)–(4): Log District Population in Year *t*

Lake Centroid: Omitted Year = 1963; 1956	***South CMR Full Lake***		***South CMR Full Lake***			***South CMR Full Lake***	
	(1)	***(2)***	***(3)***	***(4)***		***(3) Cont'd.***	***(4) Cont'd.***
Proximity to Lake (log) 1963			0.27* [0.14]	0.38* [0.20]			
Proximity to Lake (log) 1967	-0.19** [0.08]	-0.36*** [0.13]	0.03 [0.15]	0.02 [0.23]	$\beta_{31967} - \beta_{31963}$	-0.24*** [0.09]	-0.36*** [0.12]
Proximity to Lake (log) 1976	-0.27** [0.12]	-0.55** [0.22]	-0.08 [0.22]	-0.16 [0.31]	$\beta_{31976} - \beta_{31963}$	-0.35* [0.20]	-0.55** [0.26]
Proximity to Lake (log) 1987	-0.40*** [0.14]	-0.80*** [0.27]	-0.12 [0.16]	-0.23 [0.23]	$\beta_{31987} - \beta_{31963}$	-0.39** [0.19]	-0.61** [0.26]
Proximity to Lake (log) 2005	-0.36** [0.16]	-0.72** [0.34]					
Unit (113; 47) FE, Year (5; 6) FE	Y	Y	Y	Y			
District (47) Trends; Controls	Y	Y	Y	Y			

Notes: (1)–(2): 113 subdistricts*5 yrs = 565 obs. (3)–(4): 47 districts * 6 yrs = 282 obs. South CMR = centroid of the Southern section of the lake that is within Cameroon's territory. Full Lake = full lake's centroid. Conley SEs (100 Km).

standard deviation in proximity to the lake is associated with a 0.68 and 1.01 standard deviation decrease in log population in 1976 and 1987, respectively.

In the post-1995 period (year 2005), when the lake had partially recovered from its size reduction (82 percent of its pre-1965 size), the negative effect of being close the lake still exists (-36 percent). The results from Col. (1) can also be seen graphically in Figure 3.2b. As seen, standard errors increase over time, which suggests heterogeneity in the effects. Col. (2) then presents the results when lake proximity is constructed using the Euclidean distance to the centroid of the whole lake area. Results are now stronger, for possibly the same reasons as in Niger.

Because we only have one pre-1965 year, we cannot test for parallel trends in the subdistrict dataset. Relying on districts instead, we add the year 1956 to the analysis (47 districts x 6 years = 282 observations). We then use the same specification as for the subdistrict analysis except the omitted year is now 1956. However, since district-specific trends are included, one of the interacted effects cannot not estimated (we omit the year 2005). As seen in cols. (3)–(4), a positive, not negative, effect is observed in 1963 (relative to 1956). If we omit 1963 instead of 1956, we then observe very negative and significant effects post-1965 (last two columns). The effects are similar to the effects at the subdistrict level (first two columns). Figure 3.2b then shows these results graphically.

3.5.3 Effects on Total Population for Chad, 1948-2009

For Chad, we have 138 subdistricts x 5 years = 690 observations (the omitted year is 1948). Chad contains in its territory portions of both the northern and southern pools of Lake Chad. Because of the presence of the Grand Barrie`re, the northern pool was particularly vulnerable to droughts. We thus expect strong effects for areas close to the northern pool. Furthermore, households who relied on resources in the northern pool area could have migrated south closer to the southern pool, whose more eastern areas in Chad were never completely dry. Negative population growth effects in the southern pool area could be thus partially, or more than, compensated by migration from the northern pool area. In contrast, in Niger and Cameroon where residents only had access to one pool, between-pool migration was not possible.

Table 3.3: Effect of Proximity to the Lake, Total Population, Chad 1948–2009

Dependent Variable:	***Log Subdistrict Population in Year t***						
Lake Centroid in Chad: Omitted Year = 1948	***North (1)***	***Full (2)***	***South (3)***	***North (4)***	***South***	***North***	***Lake Fitri (5)***
Proximity to Lake (log) * 1953	-0.03 [0.04]	-0.01 [0.05]	-0.06 [0.07]	0.07 [0.06]	-0.15* [0.08]	0.00 [0.04]	0.08** [0.04]
Proximity to Lake (log) * 1965	0.23*** [0.09]	0.18** [0.09]	0.25** [0.12]	0.24* [0.14]	-0.03 [0.15]	0.19** [0.09]	-0.13 [0.09]
Proximity to Lake (log) * 1993	-0.29*** [0.09]	-0.03 [0.12]	0.10 [0.09]	-0.46** [0.23]	0.17 [0.23]	-0.28** [0.11]	0.03 [0.15]
Proximity to Lake (log) * 2009	-0.37*** [0.12]	-0.14 [0.17]	-0.09 [0.18]	-0.22 [0.17]	-0.30 [0.27]	-0.36*** [0.13]	0.02 [0.18]
$\beta_{1993} - \beta_{1965}$	-0.52*** [0.14]	-0.22 [0.19]	-0.15 [0.11]	-0.70** [0.32]	0.21 [0.23]	-0.47*** [0.15]	0.16 [0.12]
$\beta_{2009} - \beta_{1965}$	-0.60*** [0.15]	-0.32† [0.21]	-0.35** [0.16]	-0.46*** [0.12]	-0.27 [0.20]	-0.55*** [0.15]	0.15 [0.13]
Subdistrict (138) FE, Year (4) FE	Y	Y	Y	Y		Y	
District (36) Trends, Controls	Y	Y	Y	Y		Y	

Notes: 138 subdistricts x 5 years = 690 obs. "North TCD" = centroid of the Northern section of Lake Chad that is within the territory of Chad. "Full TCD" = centroid of the Lake Chad area that is within the territory of Chad. "South TCD" = centroid of the Southern section of Lake Chad that is within the territory of Chad. "Lake Fitri" = centroid of Lake Fitri (fully contained within Chad). Conley SEs (100 Km). † p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

In col. (1) of Table 3.3, proximity to Lake Chad is defined using the logged Euclidean distance to the centroid of the northern pool area that is within Chad's territory. In col. (2) we use the centroid of the whole lake area that is contained within Chad's territory. In col. (3) we use the centroid of the southern pool area that is within Chad's territory. Lastly, in col. (4), we simultaneously consider the northern pool centroid and the southern pool centroid.

As seen in col. (1), there is no effect in 1953 (relative to 1948) but there is a positive effect by 1965, thus indicating a positive pre-trend. If anything, households were disproportionately settling close to the lake before it started shrinking.[266] We then observe a strong negative effect in 1993 which became even more negative by 2009. In 1993 (when the lake was 92 percent smaller), the effect is -0.29***. Relative to the year 1965, the effect is even stronger, at -0.52***, implying that halving the distance to the lake is associated with a 52 percent relative decline in population. By 2009, this decline was 60 percent. Now, in terms of standardized effects, a one standard deviation in proximity to the lake is associated in 1993 with a 0.94 standard deviation in log population. Finally, the effects when omitting the year 1965 are represented visually in Figure 3.2c.

If we consider instead the centroid of the whole lake area within Chad (col. (2)), the post-1965 effects are still negative, but not significant. If we only consider the centroid of the southern pool area within Chad (col. (3)), only the 2009 effect is negative and significant (relative to the year 1965). Lastly, if we simultaneously consider the northern and southern pool effects (col. (4)), we find very negative post-1965 effects for the northern pool and a positive, but not significant, effect for the southern pool in 1993, suggesting that some areas closer to the southern pool may have indeed received migrants from the northern pool. In 2009, both effects are negative (however, not significantly so for the southern pool),

266 Recall that population data circa the year 1965 uses population data from the years 1962–1964 as a baseline. For about half of the country, information from 1968 is also used, hence the need to always include as a control a dummy if 1968 information was ever used to recreate subdistrict population, which we interact with year fixed effects.

possibly because households realized that the southern pool was on its way to become as permanently affected as the northern pool.

Next we utilize Lake Fitri as a placebo check of our analysis of the effects of Lake Chad shrinking. The location of Lake Fitri can be seen in Map 3.1. According to R. Hughes, J. Hughes, and Bernacsek 1992, the lake is located in a seasonally inundated plain that is fed by the Batha river that carries water all the way from the East of the country and the Ouaddai massif in particular. The size of Lake Fitri thus depends on rainfall at the border between Chad and Sudan. While Lake Fitri's water levels have changed over time, it has not shrunk like Lake Chad. Because Lake Fitri provides rural households with similar livelihood possibilities as Lake Chad does (e.g., fishing, farming, and cattle herding), it provides a good placebo test of whether the effects observed in Lake Chad are a consequence of changes in lake-related economic activities for the whole region instead of local economic effects limited to the Lake Chad area.

In col. (5), we report results when simultaneously including the Lake Chad variables (based on the centroid of the northern pool) and year fixed effects interacted with proximity to Lake Fitri (the negative of the logged Euclidean distance to Lake Fitri's centroid). As seen, no effects are observed for Lake Fitri. If anything, a positive and significant effect is observed in 1948–1953, hinting that populations were moving closer to this lake before 1953. However, the 1965, 1993 and 2009 effects are similar to the 1953 effect, indicating stable local population patterns after 1953. Thus, the effects observed for Lake Chad are specific to the Lake Chad region.

To summarize, we find strong negative effects of proximity to the lake during the shrinking period and limited recovery post-shrinking. The effects appear causal as no negative pre-trends are observed and no negative effects are found for Lake Fitri, another important lake. Finally, the effects are strong in the three countries, despite these countries having different geographies and institutions, which strengthens the internal and external validity of our results. As seen in Figure 3.2d that shows the water level loss (percent) of Lake Chad relative to the year 1965 as well as the post-1965 effects (percent) of the three countries in 1967–2012, the effects are also relatively similar between Cameroon and Niger. The long-term effects are then stronger in Chad, which contains a larger share of the lake than the other two countries. In the late 1980s, and using 1990 country populations as weights, we find an average relative population decline of 43 percent. Circa 2010 (thus using 2010 populations as weights), the average decline is almost unchanged at 41 percent.

3.5.4 Alternative Analysis Using Distance Bins and Population Reallocation

For a given country-year, our baseline specification allows us to compare population growth patterns for locations closer vs. farther away from the lake. As such, it has the advantage of making us estimate only one coefficient per country-year, which facilitates the exposition of the results. However, it does not tell us how the effect varies with proximity to the lake. In particular, we could imagine different scenarios with population reallocating to non-shore areas located not too far from the lake or non-shore areas located far away from the lake.

We thus use the model of eq. (1) but instead of having only one variable capturing proximity to the lake we now use several dummies based on the Euclidean distance between a subdistrict's centroid and the selected lake centroid. More precisely, the mean land area of the 113 Cameroonese subdistricts, 138 Chadian subdistricts and 119 Nigerien subdistricts is about 9.1, 10.6 and 4.2 thousand sq km, respectively. Were these subdistricts shaped like a circle, their diameter would be 108, 116 and 72 km, respectively. Thus, the distance-based bins cannot be too small (e.g., 0–100 and 100–200 km), otherwise each bin would include very few subdistricts, which would lead to less precisely estimated effects. At the same time, if the bins are too large (e.g., 0–250 and 250–500 km), we could miss local effects of the lake shrinking.

For each country, if we restrict the sample to subdistricts whose Euclidean distance to the lake is below the median, we find that the 5th percentile value in the distance to the lake is 157, 196 and 125 km for Niger, Cameroon and Chad, respectively. We thus use bins of 150 km. More precisely, we create dummies if the subdistrict is located within 0–150, 150–300 and 300–450 km from the lake and interact the dummies with the year fixed effects.[267]

We omit the last year of available data before 1965 (incl.), so 1962, 1963 and 1965 for Niger, Cameroon and Chad, respectively. The effects are thus estimated relative to the early 1960s, just before the lake began shrinking. In Table 3.4, we then only report the interacted effects for the years closest to 1990 (1988, 1987 and 1993, respectively)—at the end of the shrinking period—and 2010 (2012, 2005 and 2009, respectively)—after which the lake had started recovering. More precisely, for subdistricts s and years t and each country at a time, the model is as follows:

$$ln(Total\ Pop.)_{s,t} = \alpha + \sum_{s}\sum_{v} \beta_v, s \times Bin_s \times I_{v=t} + \lambda_s + \theta_t + D_s \times t + X_s B_{s,t} + \mu_{d,t} \quad (2)$$

where $ln(Total\ Pop.)_{s,t}$ is the log of total population in subdistrict s in year t and our variables of interest are the interactions between the three distance bin dummies (0–150, 150–300 and 300–450 km) and the year dummies. As before, we add subdistrict (λ_s) and year (θ_t) fixed effects, as well as district-specific linear trends ($D_s \times t$) and several time-invariant controls ($X_s B_{s,t}$) interacted with year effects. We then use Conley standard errors (cut-off of 100 km).

Table 3.4: Effect of Proximity to the Lake, Total Population, Flexible Specification

Dependent Variable:	Log Subdistrict Population in Year t								
Country (Centroid): Omitted Yr = Early 60s	Niger (North)			Cameroon (South)			Chad (North)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0–150 Km*ca.1990	-0.36***	-0.46***	-0.64***	-0.43***	-0.45**	-1.22***	-0.56*	-0.80**	-0.82*
	[0.05]	[0.08]	[0.08]	[0.15]	[0.20]	[0.23]	[0.31]	[0.37]	[0.44]
150–300 Km*ca.1990		-0.42***	-0.60***		-0.08	-0.85***		-0.18	-0.19
		[0.09]	[0.08]		[0.10]	[0.13]		[0.15]	[0.27]
300–450 Km*ca.1990			-0.07			-0.88***			0.00
			[0.05]			[0.13]			[0.16]
0–150 Km*ca.2010	-0.21**	-0.31**	-0.63***	-0.45**	-0.35	-1.41***	-0.23	-0.98***	-0.99***
	[0.09]	[0.15]	[0.15]	[0.21]	[0.27]	[0.27]	[0.21]	[0.24]	[0.29]
150–300 Km*ca.2010		-0.1	-0.42***		0.09	-0.98***		-0.95***	-0.96***
		[0.11]	[0.09]		[0.06]	[0.09]		[0.19]	[0.24]
300–450 Km*ca.2010			-0.05			-1.08***			0.02
			[0.08]			[0.06]			[0.02]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
District Trends, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Obs.: Niger (1951–2017): 119 subdist. x 17 yrs = 2,023. Cameroon (1963–2005): 113 subdist. x 5 yrs = 565. Chad (1948–2009): 138 subdist. x 5 yrs = 690. Niger (North) = centroid of the Northern section of Lake Chad that is within the territory of Chad. Cameroon (South) = centroid of the Southern section of the lake that is within Cameroon's territory. Chad (North): centroid of the Northern section of Lake Chad that is within the territory of Chad. For Niger, Cameroon and Chad, we omit 1962, 1963 and 1965, respectively. We interact the 0–150, 150–300 and 300–450 km dummies with the year fixed effects but only report the interacted effects for the years closest to 1990 (1988, 1987 and 1993, respectively) and 2010 (2012, 2005 and 2009, respectively). Conley SEs (100 Km). † p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

267 In Niger, Cameroon and Chad, these bins correspond to (2,3,14), (1,8,4) and (6,14,10) subdistricts, respectively.

For Niger (cols. (1)–(3)), we find strong negative effects for the 0–150 km bin. Circa 1990, the effect for the 150–300 km bin is then as strong as the effect for the 0–150 km bin. However, in the long run (c. 2010), the 150–300 km effect is smaller than the 0–150 km effect. Therefore, recovery was only partial and only concerned the subdistricts located slightly farther away from the lake. For Cameroon and only including the 0–150 km and 150–300 km dummies ((4)–(5)), we find a strong negative effect for the 0–150 km bin. This effect is then weaker, and not significant, in the long run ((5)). However, if we also include the 300–450 km dummies, then the effects become very negative until 450 km (incl.), both in the short-run and the long-run ((6)).

For Chad ((7)–(9)) and the medium run (c. 1990), we find a strong negative and significant effect for the 0–150 km bin only. The effect remains as strong in the long run. By then, the 150–300 km bin effect had also become very negative and significant.[268]

Lastly, the last spatial lags included do not have positive significant coefficients. Thus, populations did not necessarily "reallocate" to the vicinity of disaster-struck locations. Instead, the populations that would have stayed in/moved to the areas close to the lake in the absence of the shock might have stayed in/moved to other areas of the country somewhat proportionally.

268 For Niger and Chad where we have several years of data before 1965, we also verify that the coefficients of the pre-1965 interactions are never positive and significant, which would suggest negative pre-trends (not shown). Some of the interactions have a negative and significant coefficient, indicating positive pre-trends for a few distance bins, consistent with the pre-trends already observed when using (-) log distance as our measure of proximity to the lake.

3.6 Effects on Cities and "Refugee" Urbanization

In the previous sections, we showed how the shrinking of Lake Chad negatively impacted total population levels in the areas close to the lake. Since rural sectors were heavily reliant on the lake's water level, and since the regions surrounding the lake were little urbanized in 1965, our interpretation of the effects is that the effect was driven by rural decline, not urban decline.

To test that more formally, we now examine how cities were impacted. In particular, cities in the area might have been negatively affected either *directly*, due to the fact that the lake was used for commerce in a context of high road-based transportation costs and non-existent railroads in the area, or *indirectly*, because of the impact on the rural sector—via reduced fishing, farming and cattle herding—which then impacted the urban sector via rural—urban linkages. We call this scenario the "the rural disaster-led urban underdevelopment scenario."

At the same time, if individuals see reduced economic opportunities in the rural sector close to the lake, they may transition to the urban sector and thus migrate to cities, which could spur urbanization. In that case, cities grow because of a natural disaster, not economic development *per se*. We call this scenario the "the rural disaster-led urban development scenario."

Therefore, the effect of the lake shrinking on city population growth is ambiguous. It could be negative (first scenario) or positive (second scenario), for example depending on rural-urban linkages (i.e. how city growth is affected by rural economic decline) and the absorptive capacity of cities there (i.e. how negatively wages respond to increased migration flows and labor supply).

For our city population analysis, we use the same bin specification (2) as for our total population estimations except the unit of analysis is a city, which we define as a locality of at least 5,000 inhabitants. As shown by Jedwab and Vollrath 2015, the mean population threshold used in the world to define cities is 4,500. Next, we restrict the analysis to the post-1950 period, to consider the same period as for the total population analysis. Finally, we consider three dependent variables: (i) the log of (city population + 1) in year t (cols. (1)–(3) of Table 3.5);[269] and (ii) two dummies equal to one if the city had already reached 5K (cols. (4)–(6)) or 20K (cols. (7)–(9)) by year t, respectively. Note that we consider 20K to study large cities separately.

For Niger, between 1965 and 2012, the respective number of 5K+ cities and 20K+ cities increased from 14 to 161 and from 4 to 26. For Cameroon and the years 1965 and 2005, the same numbers increased from 51 to 173 and from 10 to 54. For Chad and the years 1964 and 2009, the same numbers increased from 11 to 94 and from 4 to 23. Unlike in developed countries, there are relatively few 20K+ cities. Their emergence likely captures local economic development in a different way than 5K+ cities. The growth of 5K+ cities is more likely connected to rural economic development. First, as rural agro-towns grow, they are more likely to pass the 5,000 threshold. Second, the economic sectors of small cities depend disproportionately more on economic development in their surrounding rural areas. For example, fishermen, farmers and cattle herders may purchase goods and services from local cities, and local cities may serve as trading stations for the goods they produce and sell to larger cities farther away.

269 If the locality's population is less than 5,000, we replace it by 0.

Table 3.5: Effect of Proximity to the Lake, City Population, Flexible Specification

Dependent Variable: Omitted Year=Early 60s	***Log City Population in t***			***Dummy City Pop. ≥5K t***			***Dummy City Pop. ≥20K t***		
	(1)	***(2)***	***(3)***	***(4)***	***(5)***	***(6)***	***(7)***	***(8)***	***(9)***
Panel A:				Niger (166 Cities x 17 Years = 2,822 Obs.)					
0–150 Km*ca.1990	3.34**	3.52**	4.09**	0.35**	0.37**	0.44**	0.13	0.14	0.14
	[1.56]	[1.67]	[1.77]	[0.17]	[0.18]	[0.19]	[0.14]	[0.15]	[0.15]
150–300 Km*ca.1990		1.85	2.37		0.21	0.28		0.14	0.14
		[2.94]	[3.02]		[0.33]	[0.34]		[0.15]	[0.14]
300–450 Km*ca.1990			1.78**			0.22**			0.01
			[0.83]			[0.09]			[0.02]
0–150 Km*ca.2010	0.20	0.18	0.68	-0.07	-0.08	-0.01	0.75**	0.76**	0.71**
	[1.89]	[2.04]	[2.13]	[0.21]	[0.23]	[0.24]	[0.32]	[0.35]	[0.35]
150–300 Km*ca.2010		-0.23	0.23		-0.03	0.03		0.10	0.05
		[1.65]	[1.74]		[0.18]	[0.19]		[0.31]	[0.31]
300–450 Km*ca.2010			1.57			0.21*			-0.18***
			[1.03]			[0.11]			[0.06]
Panel B:				Cameroon (179 Cities x 18 Years = 3,222 Obs.)					
0–150 Km*ca.1990	3.43***	2.94	3.65*	0.34**	0.30	0.42*	0.18*	0.17	0.21**
	[1.24]	[2.20]	[2.05]	[0.13]	[0.22]	[0.23]	[0.10]	[0.21]	[0.08]
150–300 Km*ca.1990		-0.15	0.79		-0.01	0.13		0.02	0.05
		[1.27]	[1.68]		[0.12]	[0.20]		[0.16]	[0.12]
300–450 Km*ca.1990			0.34			0.08			0.04
			[2.38]			[0.26]			[0.23]
0–150 Km*ca.2010	-0.60	-2.52	0.00	-0.14	-0.33	0.00	0.14	0.08	0.00
	[1.17]	[2.47]	[0.00]	[0.13]	[0.24]	[0.00]	[0.19]	[0.43]	[0.00]
150–300 Km*ca.2010		-2.17*	0.65		-0.22	0.14		-0.06	-0.13
		[1.30]	[1.69]		[0.14]	[0.18]		[0.29]	[0.18]
300–450 Km*ca.2010			2.03			0.27			-0.08
			[2.29]			[0.23]			[0.43]
Panel C:				Chad (100 Cities x 12 Years = 1,200 Obs.)					
0–150 Km*ca.1990	-1.13	-2.29*	-4.26***	-0.10	-0.25*	-0.46***	0.03	0.10	0.16
	[1.46]	[1.35]	[1.44]	[0.15]	[0.15]	[0.15]	[0.02]	[0.16]	[0.20]
150–300 Km*ca.1990		-1.48	-3.65*		-0.19	-0.41**		0.04	0.12
		[1.78]	[2.01]		[0.20]	[0.21]		[0.15]	[0.20]
300–450 Km*ca.1990			-2.55			-0.26			0.09
			[1.58]			[0.17]			[0.13]
0–150 Km*ca.2010	-1.28	-1.34	0.21	-0.09	-0.14	0.06	-0.20***	-0.04	-0.26
	[1.20]	[2.12]	[2.77]	[0.13]	[0.23]	[0.30]	[0.06]	[0.33]	[0.44]
150–300 Km*ca.2010		1.39	3.27		0.12	0.35		0.18	-0.07
		[2.00]	[3.04]		[0.22]	[0.33]		[0.36]	[0.48]
300–450 Km*ca.2010			2.14			0.27			-0.29
			[2.36]			[0.26]			[0.23]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
District Trends, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: For Niger, we use the centroid of the Northern section of Lake Chad that is within the territory of Chad. For Cameroon, we use the centroid of the Southern section of the lake that is within Cameroon's territory. For Chad, we use the centroid of the Northern section of Lake Chad that is within the territory of Chad. For Niger, Cameroon and Chad, we omit 1965, 1965 and 1964, respectively. We interact the 0-150, 150-300 and 300-450 km dummies with the year fixed effects but only report the interacted effects for the years closest to 1990 (1988, 1987 and 1993, respectively) and 2010 (2012, 2005 and 2009, respectively). Conley SEs (100 Km). † $p<0.15$, * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

3.6.1 Effects on City Population Sizes for Niger 1951–2012

For Niger, we have 166 cities x 17 years = 2,822 observations. The effects are then estimated relative to 1965, the omitted year.[270] As seen in cols. (1)–(3) of Panel A of Table 3.5, positive, not negative, effects are observed on log city population in the shorter run (c. 1990). The short-run effects are especially strong close to the lake (0–150) and decrease with distance to it. In particular, while we previously found that subdistricts close to the lake grew about 60 percent slower than other locations (cols. (1)–(3) of Table 3.4), these results suggest that cities close to the lake grew 400 percent faster than other cities on average. While 400 percent seems high, note that most cities were initially small or non-existent in our three countries pre-1965. Consistent with an African context of high migration rates and fast demographic growth (Jedwab, Christiaensen, and Gindelsky 2017), cities in our three countries then grew particularly fast during the post- 1965 period. For example, Niger's total urban population had increased by 500 percent by 1988.

In the longer run (c. 2010) and the specification with three distance bins, we still see positive effects but these are weaker and not significant. There are several possible interpretations for the reduction in the effects. First, economic refugees from the Lake Chad area may have only temporarily settled in the cities around the lake, the time for them to find the resources to pay the costs of migration to other cities farther away. Second, economic decline in rural areas may have eventually impacted the urban sector in the area, thus causing cities in the area to relatively lose inhabitants post-1990.

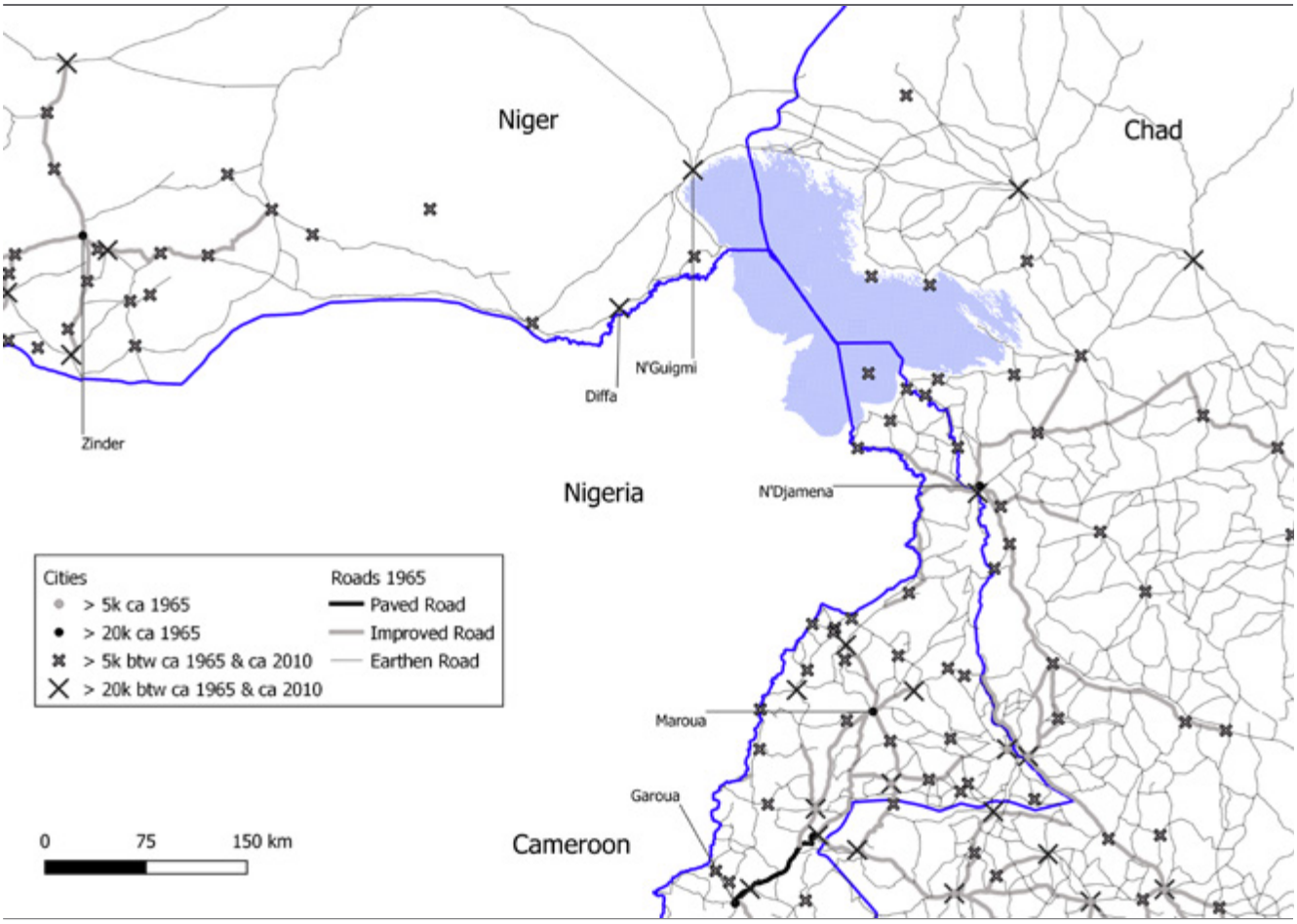
Now, are the effects driven by smaller or larger cities? If the dependent variable is a dummy if the city had already reached 5,000 by 1990 ((4)–(6)), we find strong effects closer to the lake in the shorter run (c. 1990; a 40 percent higher probability for the 0-150 km bin) and no effect in the longer run (c. 2010). However, the lack of long-run effects is misleading because almost all cities were above 5,000 then. Thus, with a dummy almost always equal to one, the effect is identified off a very few cities only. Instead, it is more relevant to study the effect on 20K+ cities. Indeed, only 16 percent of the 166 cities had reached that threshold by 2010 (in comparison, 8 percent of the 166 cities had already reached 5K by 1965). As seen in cols. (7)–(9), when the dependent variable is a dummy if the city is above 20,000, there is a strong effect in the shorter run that becomes much stronger in the longer run. In particular, the coefficients suggest that, close to the lake, there is a 70 percent higher probability of cities reaching 20K.

To conclude, in Niger's case, we find strong positive effects on urbanization during the shrinking period, which led in the longer run to the rise of larger cities in the area. Thus, in Niger, the results are consistent with the rural disaster-led urban underdevelopment scenario.

Which cities in particular did benefit? This can be examined in Map 3.4. Circa 1965, there were no 5K+ cities (grey circles) in the East, despite the existence of many small settlements close to the lake. The closest 20K+ city was Zinder, 474 km from the lake. Roads in the East were then dirt roads. However, since it does not rain much in the area, dirt roads are comparable to improved (gravel) roads in the south-west of the country (Jedwab and Storeygard 2020). Assuming driving speeds of 40 km per hour, the driving time from the lake to Zinder must have been at the very least 12 hours. Two days of driving were more likely, given roads are not straight lines and road conditions more generally. In this context, given the initial lack of cities close to the lake, it is perhaps not surprising that two 20K+ cities appeared: Diffa and N'Guigmi. Diffa was a large village in 1965. Yet, by 2012, it had become Niger's 11th largest city. N'Guigmi was historically located on the shore of the lake. As explained by Geels 2006, the town was before 1965 a center for

270 Given the high number of controls and when estimating the model with several distance bin dummies interacted with year fixed effects, we need to omit one more year. We choose 1962, the second closest year before the year 1965.

Map 3.4: Evolution of City Population Sizes around Lake Chad, ca. 1965–ca. 2010



Notes: The map shows, for the Lake Chad area, the location of 5K+ and 20K+ urban settlements circa 1965, when the lake started shrinking, and circa 2010, at the end of our period of study. We also indicate regionally important (20K+) cities in the 1960s such as Diffa, N'Guigmi and Zinder in Niger, N'Djamena in Chad, and Maroua and Garoua in Cameroon. Finally, we show paved roads, improved roads, and earthen roads, all circa 1965.

fishing communities. During the mid-1970s the lake's shore was 85 km away while it was 45 km away in the 2000s. Thus, we might have expected N'Guigmi to have been negatively impacted by the shrinkage of the lake. Its dramatic growth from 3000 people in 1962 to 25,000 today must have been driven by the locality functioning as a "refugee settlement" for individuals who lost their rural livelihoods. Finally, since we find significant long-run effects on 20K+ cities but no significant long-run effects on overall city population growth, it must be that the shrinkage of the lake increased urban concentration in the area.

3.6.2 Effects on City Population Sizes for Cameroon 1951–2012

For Cameroon, we have 179 cities x 18 years = 3,222 observations. The effects are then estimated relative to 1965, the omitted year. As seen in cols. (1)–(3) of Panel B in Table 3.5, we find in the shorter run (c. 1990) strong positive effects close to the lake. In the specification with three distance bins (col. (3)), the effect for the 0–150 km bin is 3.65. Thus, cities closest to the lake grew 365 percent faster than other cities on average. In the longer run (c. 2010), no clear effect is observed. If we rely on the specification with three distance bins (col. (3)), there is no effect at all for the 0–150 km bin, possibly because of the same reasons as for Niger.

Now, we find relatively similar patterns if the dependent variable is a dummy equal to one if the city has reached 5K (cols. (4)–(6)). The shorter-run effects for 20K cities are then positive and relatively similar to what we found for Niger (cols. (7)–(9)). However, in the longer run, the effects have disappeared, unlike what we found for Niger. To conclude, in Cameroon's case, we also find positive effects on urbanization during the shrinking period. Thus, in Cameroon, the results are consistent with the rural disaster-led urban underdevelopment scenario, at least during the disaster period. However, in the longer run, no clear effect is observed.

For the areas closest to the lake, why are the shorter-run effects overall weaker in Cameroon than in Niger and why have these effects disappeared in the longer run, unlike what we saw for Niger? These results make sense when visually inspecting how many 5K+ and 20K+ cities existed in 1965 vs. emerged between 1965 and circa 2010 (we use 2005 for Cameroon). As can be seen in Map 3.4, the Cameroonian areas close to the Lake had no cities in 1965. The closest city was Maroua, which was already larger than 20K in 1964. Maroua was 252 km from the lake, so closer to the lake than Zinder was in Niger. Garoua, farther away (407 km), was also larger than 20K in 1964.[271]Then, as can be seen, many small cities eventually emerged close to the lake and a few 20K+ cities also emerged close to Maroua. Thus, the existence of Maroua and Garoua, two cities that were already economically important in the 1960s, might have prevented other 20K+ cities from emerging closer to the lake (or at least at a higher rate than observed elsewhere). If anything, relying on the specification with three distance bins (col. (3)), we see positive (but not significant) effects for the 150–300 km bin (close to Maroua) and the 300–450 km bin (Garoua).

3.6.3 Effects on City Population Sizes for Chad 1950–2009

For Chad, we have 100 cities x 12 years = 1,200 observations. We use 1964, the first year before 1965, as the omitted year.[272] As seen in Panel C of Table 3.5, and unlike what we found for Niger and Cameroon, strong negative effects can be observed in the shorter run (c. 1990). However, these negative effects have disappeared in the longer run (c. 2010). In the specification with three distance bins (col. (3)), no effect is observed within 150 km and positive effects are observed for the 150–300 and 300–450 km bins (much like what we found for other two countries).

Likewise, in the shorter run, we find positive but not significant effects if the dependent variable is a dummy if the city has reached 20 km (cols. (7)–(9)). In the longer run, we actually find negative effects but they are also not significant. Overall, in Chad and in the longer run, the shrinkage of the lake did not reduce city population sizes. However, given the possibly negative extensive margin effects for larger cities, it must be that small cities grew relatively fast.

The lack of a positive effect for 20K+ cities is not surprising given the presence of N'djamena, Chad's largest city, 230 km away from the lake. As can be seen in Map 3.4, only one 20K+ city appeared in the vicinity of the northern part of the lake. There were then more 5K+ cities close to the former shore of the lake. Thus, it is possible that lake "refugees" with skills that allowed them to be absorbed by more urban sectors disproportionately went to the region of N'djamena instead of joining the ranks of smaller cities that might have otherwise passed the 20K threshold.

271 Ndjamena, the capital and largest city of Chad, is not far, but on the other side of the border, and while borders are usually porous in the region, Cameroonians typically do not migrate to Chad, a significantly poorer country.

272 Given the high number of controls and when estimating the model with several distance bin dummies interacted with year fixed effects, we need to omit one more year. We choose 1961, the second closest year before the year 1965.

To conclude, across the three countries and focusing on the specification with three distance bins (col. (3)), the long-run effects on city population sizes are positive, however never significantly so. Therefore, some cities grew as a result of the shock and the observed (relative) population decline observed close to the lake must have been driven by rural population. We test this more formally by using the specification with three distance bins (eq. (2)) and studying how their shorter and longer run effects on log (total population) in year t vary when also controlling for the log of (total urban population + 1) in year t (total urban population is the total population of cities above 5K in t, which is sometimes equal to 0). The regressions are thus the same as in Table 3.4 except that we control for urban growth. When doing so, the effects are either unchanged or become even more negative (not shown, but available upon request), thus confirming that the observed relative decline in total population is driven by population decline.

Depending on the initial economic geography of the country, we then find different responses for small cities vs. larger cities. In Niger, we find strong effects for 20K+ cities, hence urban concentration in the lake area. In both Cameroon and Chad, we find nil or negative (but not significant) effects for 20K+ cities. Already existing 20K+ cities such as Maroua and Garoua in Cameroon and N'djamena in Chad must have acted as a pull factor for lake refugees, thus preventing the emergence of medium-sized cities close to the lake. As a result, slower rural in-migration to the area or faster out-migration of rural residents from the area must have accelerated urbanization, in many cases away from the areas close to the shore of the lake.

3.7 Governmental Responses to the Crisis

One important question is whether governments, observing the increasingly negative impacts of the lake during the shrinking period, used public infrastructure investments as a way to mitigate the effects of the shock or actually under-invested in the areas. Unfortunately, for most African countries, there is limited data on public investments over such a long period of time.

However, and for Kenya in 1964–2002 only, Burgess et al. 2015 construct localized measures of road investment that come from Michelin maps. They then use this data to show how politically connected districts disproportionately receive roads in more autocratic regimes.[273] Jedwab and Storeygard 2020 also use the same type of data but for the whole continent and the period 1965–2014 to study the effects of roads on urbanization. We thus rely on their geospatialized data to obtain for each country-subdistrict and each year available the total length (km) of *paved* roads, *improved* (laterite or gravel) roads and *earthen* roads.[274]

We then use model (2) with the different distance bin dummies to study the effects of proximity to the lake on road investment. The results are reported in Table 3.6. In cols. (1)–(3), (4)–(6) and (7)–(9), the dependent variable is the log of (total length of paved roads + 1), (total length of improved roads + 1) and (total length of paved or improved roads + 1), respectively. The effects are estimated relative to the omitted year, 1965. In the table, we then only report the interacted effects for the years 1988—to mark the end of the shrinking period—and 2008—to capture the long-term effect of the lake shrinking.[275] Finally, note that paved roads are on average 4 times more "expensive" to build than improved roads, which are in turn 15 times more "expensive" to build than earthen roads (Jedwab and Storeygard 2019).

As seen when comparing Maps 3.4 and 3.5, Niger's government built between 1965 and 2014 paved roads all the way to the lake. The question is whether subdistricts close to the lake received relatively more road investments than other subdistricts, hence the need to examine this econometrically. As seen in Panel A of Table 3.6, in Niger we see positive shorter run (c. 1990) and longer run (c. 2010) effects on paved road construction, implying that lake areas indeed received more paved roads than other areas on average (see cols. (1)–(3)). The paving of roads nonetheless came at the expense of improved roads (cols. (4)–(6)). However, lake areas received more paved roads than they "lost" improved roads (cols. (7)–(9)). Now, if we examine when lake areas experienced more paved road building than other locations, we find that it was in the mid-1970s (not shown), by which the the lake's water level had already decline by 75 percent. The road investments were thus likely a response to the shrinkage of the lake. However, since the lake areas experienced slower population growth, it must be that the observed road investments had little impact on localized economic development (again, relative to other locations in the country). We could then also imagine that roads lowered inter-regional migration costs for lake refugees, thus accelerating outmigration to other areas in the rest of the country.

In Cameroon, there were already a few improved roads in the area in 1965 (Map 3.4). By 2014, some of these

273 As explained by Jedwab and Storeygard 2020, "Michelin uses four sources to create the maps: (i) the previous Michelin map, (ii) government road censuses/maps, (iii) direct information from its tire stores across Africa, and (iv) correspondence from road users including truckers." As such, the data is highly reliable for our purpose.

274 The available years are 1965, 1967, 1968, 1969, 1971, 1973, 1976, 1983, 1984, 1985, 1986, 1988, 1990, 1991, 1993, 1996, 1998, 2003, 2008 and 2014. No Michelin map was published for our countries of study before 1965.

275 Note that we have road data up to 2014 and also interact the distance bin dummies with the year 2014. However, to be consistent with our population estimations, we are more interested in seeing the effect circa 2010.

Table 3.6: Effect of Proximity to the Lake, Road Investments, Flexible Specification

Dependent Variable: Omitted = 1965	***Log (Paved Km + 1) t***			***Log (Improved Km + 1) t***			***Log (Paved+Impr. Km + 1) t***		
	(1)	***(2)***	***(3)***	***(4)***	***(5)***	***(6)***	***(7)***	***(8)***	***(9)***
Panel A:	Niger (166 Subdistricts x 20 Years = 2,380 Obs.)								
0–150 Km*ca.1990	0.14	2.75***	2.33***	-0.06	-3.58***	-3.31***	0.45	2.39***	2.32***
	[0.45]	[0.48]	[0.53]	[0.47]	[0.62]	[0.73]	[0.46]	[0.50]	[0.56]
150–300 Km*ca.1990		3.32***	2.97***		-3.48***	-3.26***		2.90***	2.86***
		[0.45]	[0.46]		[0.55]	[0.61]		[0.49]	[0.51]
300–450 Km*ca.1990			-0.94**			0.62			-0.07
			[0.41]			[0.73]			[0.55]
0–150 Km*ca.2010	-1.05**	3.57***	3.22***	-0.18	-6.74***	-6.63***	-0.77	2.54***	2.49***
	[0.53]	[0.69]	[0.73]	[0.67]	[0.98]	[0.98]	[0.59]	[0.69]	[0.71]
150–300 Km*ca.2010		4.12***	3.82***		-6.41***	-6.32***		3.04***	3.00***
		[0.75]	[0.75]		[0.87]	[0.87]		[0.76]	[0.77]
300–450 Km*ca.2010			-0.90*			0.40			-0.00
			[0.47]			[0.78]			[0.61]
Panel B:	Cameroon (113 Subdistricts x 20 Years = 2,260 Obs.)								
0–150 Km*ca.1990	-2.60***	-5.35***	-2.12***	2.19***	3.46***	-0.26	-0.61	-0.08	-1.19*
	[0.78]	[0.76]	[0.50]	[0.69]	[0.86]	[0.65]	[0.56]	[0.77]	[0.66]
150–300 Km*ca.1990		-2.98***	0.18		1.19**	-2.57***		0.60	-0.58
		[0.33]	[0.54]		[0.47]	[0.47]		[0.44]	[0.54]
300–450 Km*ca.1990			2.66***			-4.13***			-1.70**
			[0.69]			[0.53]			[0.67]
0–150 Km*ca.2010	-2.42**	-7.00***	0.26	3.86***	6.08***	-0.61***	0.18	0.75	-0.44**
	[0.99]	[0.96]	[0.51]	[0.73]	[0.97]	[0.22]	[0.53]	[0.71]	[0.20]
150–300 Km*ca.2010		-4.68***	2.55**		2.00***	-4.77***		0.46*	-0.78
		[0.44]	[1.04]		[0.34]	[0.72]		[0.25]	[0.54]
300–450 Km*ca.2010			7.03***			-7.30***			-1.70**
			[1.17]			[0.89]			[0.73]
Panel C:	Chad (138 Subdistricts x 20 Years = 2,760 Obs.)								
0–150 Km*ca.1990	-0.23**	-0.25*	-0.23	0.10	0.19	0.25	0.06	0.13	0.15
	[0.11]	[0.15]	[0.17]	[0.07]	[0.17]	[0.30]	[0.06]	[0.15]	[0.27]
150–300 Km*ca.1990		-0.00	0.02		0.09	0.15		0.06	0.08
		[0.10]	[0.13]		[0.13]	[0.27]		[0.12]	[0.24]
300–450 Km*ca.1990			0.03			0.10			0.03
			[0.12]			[0.24]			[0.22]
0–150 Km*ca.2010	-0.19**	-0.22	-0.21	0.11**	0.30	0.24	0.09	0.25	0.18
	[0.08]	[0.16]	[0.24]	[0.05]	[0.23]	[0.30]	[0.05]	[0.21]	[0.28]
150–300 Km*ca.2010		0.02	0.02		0.18	0.13		0.17	0.10
		[0.12]	[0.20]		[0.17]	[0.24]		[0.16]	[0.23]
300–450 Km*ca.2010			0.01			-0.09			-0.09
			[0.09]			[0.12]			[0.13]
Subdistrict FE, Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
District Trends, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y	Y

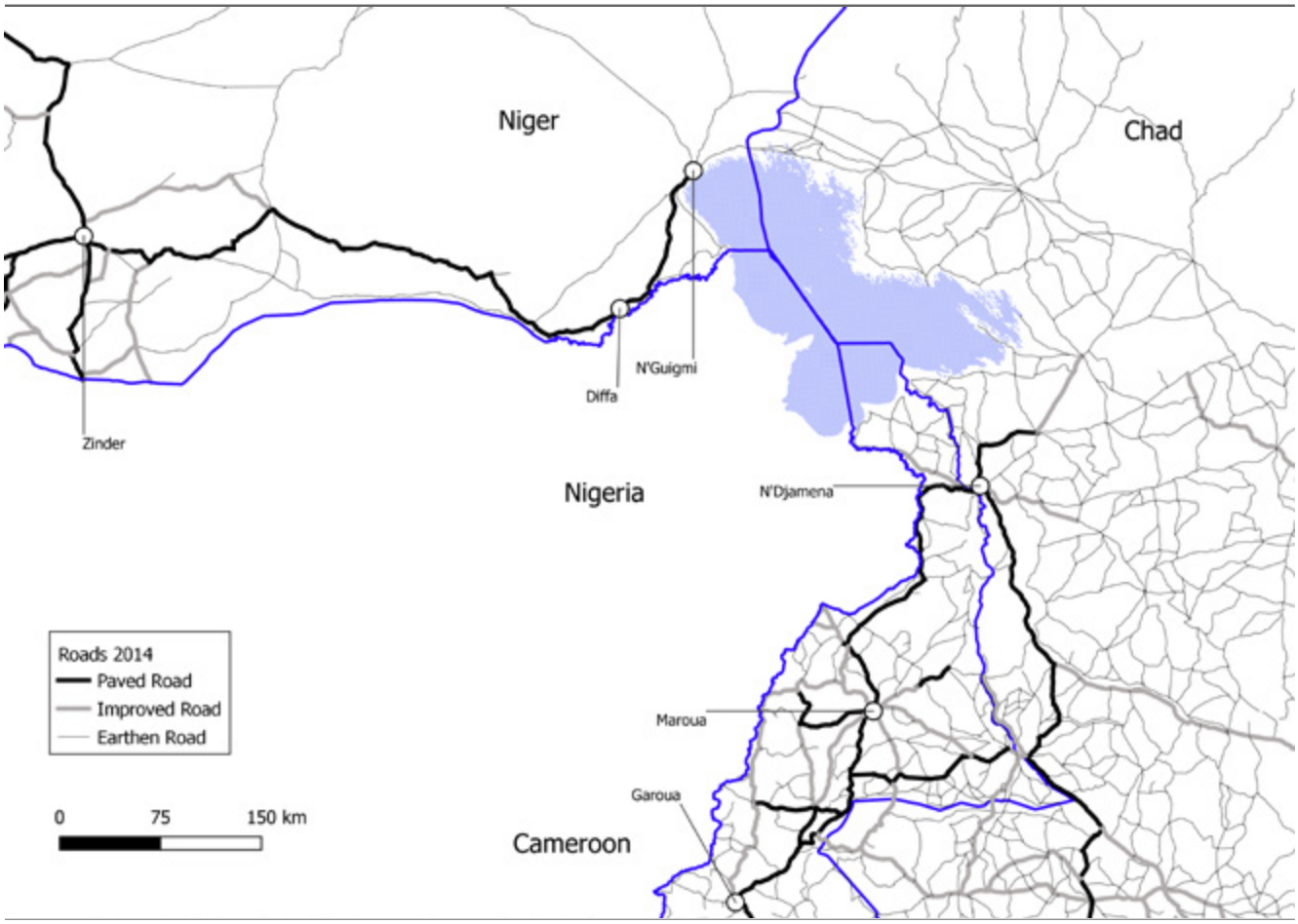
Notes: For Niger, we use the centroid of the Northern section of Lake Chad that is within the territory of Chad. For Cameroon, we use the centroid of the Southern section of the lake that is within Cameroon's territory. For Chad, we use the centroid of the Northern section of Lake Chad that is within the territory of Chad. For Niger, Cameroon and Chad, we omit 1965. We interact the 0-150, 150-300 and 300-450 km dummies with the year fixed effects but only report the interacted effects for the years 1988 and 2008. Conley SEs (100 Km). † $p<0.15$, * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

roads were paved and some earthen roads were improved, however not in the immediate vicinity of the lake (see Map 3.5). Econometrically (see Panel of Table 3.6), we observe lower levels of road investment in the Lake Chad area, except maybe farther away for the lake and for paved roads only (col. (3)). For the areas closest to the lake (0–150 km), negative shorter run and longer run effects are observed when combining paved and improved roads (col. (9)). Cameroon's government thus did not appear to respond to the shrinkage of the lake by building more roads connecting the immediate lake areas to the rest of the country.

In Chad, the areas close to the lake did not have any paved or improved road in its vicinity in both 1965 and 2014 (Maps 3.4 and 3.5). Chad's government thus did not build better roads to the area. This is confirmed econometrically in Panel C of Table 3.6. While the coefficients are not significant, we find, if anything, negative effects for paved road construction (col. (3)).

Overall, Cameroon and Chad did not particularly respond to the crisis by building more roads to the Lake Chad area. Niger did respond by building more roads but we know from our population estimations that it did not prevent population decline in the area. We nonetheless observed urban concentration in Niger, with a higher likelihood of having larger 20K+ cities. Thus, the roads might have contributed to lake refugees settling in these better connected (and possibly diversified) cities rather than staying in smaller cities as in Cameroon or Chad.

Map 3.5: Road Networks in the Lake Chad Area, ca. 2015



Notes: The figure shows for the year 2014 the location of paved roads, improved roads, and earthen roads.

3.8 Conclusion and Policy Discussion

Many of the world's lakes are disappearing. Despite an extensive literature on the economic consequences of climate change, the economic effects of diminishing lakes have not been widely investigated. We focused on Lake Chad, a vast African lake that lost about 90 percent of its surface area between 1965 and 1985, and recovered some of it post-1985. For Cameroon, Chad and Niger, we constructed a novel data set tracking total and city population patterns at a fine spatial level from the 1950s to the 2010s. We then exploited a difference-in-difference strategy to estimate the effects of Lake Chad's shrinking on nearby communities. We found relatively slower total population growth in the proximity of the lake, but only after the lake started shrinking. We did not find evidence for population recovery in the long run. We also found in many cases positive effects on the lake shrinking on city population growth nearby, which suggested that climate change might have induced "refugee" urbanization locally. Finally, we found that only Niger disproportionately built higher-quality roads to the Lake Chad area. However, comparing our different results, it did not appear to prevent population decline in the Lake Chad area.

More generally, while our work cannot fully answer the question of how governments should respond to shrinking lakes, our results suggest that such natural disasters could have permanent negative localized economic effects in poor agrarian countries. In such countries, rural decline is likely to accelerate structural change and urbanization, in some cases locally. Unless governments and the international community find ways to reverse changes due to such natural disasters, which in this case could imply diverting other rivers regionally or stopping climate change globally, the shrinkage of lakes is likely to increase already existing pressures on cities. Factors that increase the absorptive capacity of their labor and housing markets might then help mitigate the economic impact of lake shrinkages. Finally, an important policy question is how much should governments invest in infrastructure in disaster-prone areas, for example in roads that would connect these areas to less exposed locations. While roads might help the affected regions cushion the shock by diversifying away from lake-related economic activities, they may also have no impact or even a detrimental local impact by accelerating outmigration. Unfortunately, the lack of data prevents us from better analyzing which other public investments historically took place in the region and what their mitigation effects were.

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Technical Paper 3. Estimating the Spillover Economic Effects of Foreign Conflict: Evidence from Boko Haram

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4.1 Introduction

Violent conflicts present a formidable threat to regional economies. Throughout the world, border regions in many countries are possibly impacted by the cross-border economic effects of regional insurgencies in neighboring countries or national state failures, i.e. "bad neighbors". This raises two questions. First, what is the magnitude of the spill-over economic effects of foreign conflict and what are the channels through which they operate? Second, what policies can governments adopt in the potentially exposed regions to mitigate such spill-over effects?[276]

In this paper, we adopt a difference-in-difference (DiD) framework leveraging the unexpected rise of the Boko Haram insurgency in Northeastern Nigeria in 2009 to study its economic effects in *neighboring* areas in Cameroon, Chad and Niger that were *not* directly targeted by Boko Haram activities. We find strong cross-border economic effects that are likely driven by reduced trade activities, not the diffusion of conflict. Factors of local economic resilience to this foreign conflict shock then include trade diversification and political and economic securitization. More generally, conflicts, if they have regional economic effects, may necessitate regional responses.

The causal identification of the effects of conflict, and by extension of the mitigation effects of various locational factors, is complicated by a complex endogenous relationship between conflict and socio-economic conditions (Blattman and Miguel, 2010; Djankov and Reynal-Querol, 2010). Conflicts impose large economic tolls (e.g., International Monetary Fund, 2019; Trebbi and Weese, 2019). But poor economies and economic shocks also offer fertile grounds for conflicts (e.g., Miguel et al., 2004; Bazzi and Blattman, 2014; Burke et al., 2015).[277]

While poverty traps and conflict traps can reinforce each other *locally*, spatio-dynamic *spillovers* can also be present (Berman et al., 2017; König et al., 2017; Harari and Ferrara, 2018; Melnikov et al., 2020; Eberle et al., 2020). Conflict in one location can beget conflict in other locations, either via a direct expansion in space of conflict factors (e.g., armies) or because conflict in one location increases poverty, and lowers the opportunity cost of conflict labor, in other locations. Due to spill-overs that reinforce each other across locations, separately identifying local and non-local effects is difficult econometrically (Harari and Ferrara, 2018).

Studies on the impact of policies on conflict then focus on conflict prevention, management, resolution and/or reconciliation in the conflict countries themselves (e.g., Nunn and Qian, 2014; König et al., 2017; Chiovelli et al., 2018; Sviatschi, 2018). Less is known about how non-conflict countries can mitigate, in their border regions, the local economic impact of foreign conflicts.

To address some of these challenges, we exploit the exogenous rise of Boko Haram in Nigeria after 2009 and estimate its local economic effects on neighboring areas within Cameroon, Chad and Niger (CCN), so *outside* Nigeria. Between 2009 and 2014, Boko Haram became the world's deadliest terrorist group ahead of ISIL, the Taliban and Al-Shabaab (Institute for Economics

276 Examples of regional insurgencies plausibly affecting other countries include the Cabo Delgado insurgency in Mozambique (Tanzania), the ISIL insurgency in Iraq and Syria (Turkey but also Jordan and Lebanon), the insurgency in the Maghreb (other countries in West Africa), the Taliban insurgency in Afghanistan (Iran, Pakistan, Tajikistan, Turkmenistan and Uzbekistan), etc. Examples of failed states with possible regional impacts include the Central Africa Republic, the Democratic Republic of the Congo, Somalia, South Sudan, Venezuela, Yemen, Zimbabwe, etc.

277 Other studies on the effects of (absolute or relative) poverty or income shocks on conflict or terrorism include, among many others, Krueger and Malečková (2003); Brückner and Ciccone (2010); Besley and Persson (2011); Ciccone (2011); Miguel and Satyanath (2011); Enders and Hoover (2012); Dube and Vargas (2013); Jia (2014); Couttenier and Soubeyran (2014, 2015); Berman and Couttenier (2015); Crost et al. (2016); Harari and Ferrara (2018); Berman et al. (2019);McGuirk and Nunn (2020); Eberle et al. (2020). Typically, poverty and negative income shocks are associated with individual incentives to engage in conflict as well as weakened state and counterinsurgency capacity.

and Peace, 2012–2020). Until 2014, Boko Haram concentrated its terrorist activities in the Northeastern part of Nigeria close to the border with CCN *but* did not enter these countries, mostly to avoid fighting at least four government armies instead of one. As such, in CCN until 2014, the estimated effects must be due to the spill-over effects described above.

We use a simple DiD framework whereby we compare CCN areas "close to" and areas "farther away from" the Boko Haram region in the years after 2009 versus before 2009. We find a strong negative effect of Boko Haram on regional economic activities (as proxied by changes in night light intensity)—particularly for areas within 200 km from the Boko Haram region. More precisely, we find an average decline of 10 percent for the post-2009 period, and a decline of about 20 percent for places closer to the shock (within 100 km). For all places within 200 km, we find an overall effect of about 20 (50) percent by 2013 (2018), that is, 4 (9) years after the shock began. The effects appear to be driven by declines in per capita incomes rather than population outflows (or refugees inflows since we control for it). We also show that the parallel trends assumption is verified in CCN. Finally, we find no effect on local (i.e. non-Boko Haram) conflict in CCN. Therefore, the estimated spill-over effects are purely economic.

When studying the confidence intervals of the baseline effect, we find that the estimated effects range from about -30 percent to -10 percent in 2013. Thus, while most places within the 200 km region were negatively affected, some were less affected than others, which motivates us to analyze the heterogeneous effects of foreign conflict depending on initial (pre-2009) local conditions. We find stronger effects for initially more developed locations, hence more urban locations, which shows the potential importance of foreign conflict for trade. Indeed, the Boko Haram area historically served as a trade corridor between (relatively wealthier) areas of Nigeria and (relatively poorer) Cameroon-Chad to the East and Niger to the West.[278]

We then use the same econometric framework to identify factors that can help mitigate the effects of foreign conflict shocks. We find stronger mitigation effects in those areas that were initially better connected to other markets either via trade networks or transportation infrastructure (thus benefiting from a more diversified set of potential trade partners), and more politically and/or economically "secured" by government consumption via defense-related facilities (e.g., military headquarters) or public employment (e.g., social services).

This paper makes four important contributions. First of all, various studies show how economic shocks in some locations increase conflict there as well as in neighboring locations (Berman et al., 2017; König et al., 2017; Harari and Ferrara, 2018; Eberle et al., 2020; McGuirk and Nunn, 2020).[279] Two channels explain spatial diffusion. First of all, conflict factors can move (e.g., armies) or be moved (e.g., weapons) spatially. Secondly, due to economic spillovers, poverty can increase in surrounding locations, thus raising the likelihood of conflict there. We do not find any impact of Boko Haram activities in Nigeria on local (non-Boko Haram) conflict activities in CCN, and this despite significant income declines in contexts where most individuals already lived close to the subsistence level.[280] The lack of conflict spillovers does not appear to be due to the increase of government forces in the area. Our interpretation is that poverty disproportionately increased in trade-reliant urban locations. Even if the opportunity cost of conflict labor decreased, other economic factors must have dominated the previous effect and prevented conflict.

278 Likewise, we find weaker effects on "rural" outcomes. Our analysis shows no effects on measures of greenness (proxying for agricultural expansion) or land use. We, however, find effects on agricultural burning, which proxies for agricultural intensification in rural areas (Blankespoor et al., 2021), most likely as a result of reduced urban incomes.

279 There are related literatures on the determinants of the spatial diffusion of conflict (e.g., Bosker and de Ree, 2014; Novta, 2016) and economic shocks (e.g., Amarasinghe et al., 2020). These studies all highlight the role of ethnic networks. Such networks are particularly important for domestic and international trade in Africa (Fafchamps, 2003).

280 Boko Haram also had no incentive to enter CCN, at least until 2014.

Indeed, the causal mechanism of economic shocks leading to conflict is complex, and the type of economic shock and industries should mediate the effects on conflict. Positive shocks to labor-intensive industries, such as agriculture, raise wages and reduce conflict (Dal Bó and Dal Bó, 2011; Berman and Couttenier, 2015; Harari and Ferrara, 2018).[281] But positive shocks to capital-intensive industries raise the likelihood of conflict because the capital intensive industry expands at the expense of the labor intensive one, which lowers the cost of appropriation activities relative to the amount of appropriable resources. Commodity discoveries or price increases then increase violence because there is more to appropriate (Angrist and Kugler, 2008; Dal Bó and Dal Bó, 2011; Dube and Vargas, 2013).[282] In our case, the shock reduced the amount of appropriable resources and disproportionately impacted sectors that were more capital-intensive than agriculture. The trading sector is then particularly sensitive to the impact of conflict on trade costs, and economic agents may internalize that (Martin et al., 2008b, 2012). In our context, urban residents whose incomes decreased due to the shock plausibly internalized that having community members engage in conflict would further reduce incomes. Finally, the shock was for the main period of study (wrongly) seen as temporary, as it was believed that the Nigerian army, helped by international allies, would eventually eradicate Boko Haram. It may have prevented individuals from switching to more conflict-related activities.

Secondly, this paper sheds light on the *heterogeneous*, not just average, effects of conflict on growth at the subnational level. In particular, for a similar conflict "shock", the local impact may differ depending on initial economic conditions. We find stronger effects for more urban locations. Among urban locations, the least developed locations were disproportionately impacted. When studying which locations were more resilient economically to the foreign conflict shock, we find that more connected and more secure locations were better able to "weather" some of the impact of the shock. These results are, we believe, important for policy because it identifies potential factors of resilience to foreign conflict shocks. In contrast, other studies examine countries that are, or were, directly impacted by conflict (instead of indirectly via cross-border effects). In these countries, they focus on policies aimed at conflict prevention, resolution and/or management (de Ree and Nillesen, 2009; Berman et al., 2011; Rohner et al., 2013a; Nunn and Qian, 2014; Crost et al., 2014; König et al., 2017; Chiovelli et al., 2018; Sviatschi, 2018; Hartman et al., 2018; Eberle et al., 2020) or post-conflict reconciliation (Fearon et al., 2009, 2015; Blattman and Annan, 2015; Blattman et al., 2015). The government interventions that our results highlight differ from some of the policies that have been studied in the literature, partly because the affected border regions do not directly suffer deaths and destruction.[283]

Thirdly, there is a large literature on the impact of conflict on local economic development (e.g., Abadie and Gardeazabal, 2003; Nunn and Wantchekon, 2011; Besley and Reynal-Querol, 2014; Burger et al., 2015; Brodeur, 2018; Melnikov et al., 2020).[284] However, conflict often arises endogenously due to socio-economic conditions, making it difficult to measure truly causal local economic effects. Our natural experiment has the merit of being simple and allows us to estimate the effects of a non-local, more exogenous, conflict shock. However, our shock is externally less valid than in some of the other studies since it measures a cross-border effect. Also,

281 As shown by McGuirk and Burke (2020), global food price shocks increase conflict in areas without crop agriculture where most workers are net consumers of food. In food-producing areas, higher food prices may simultaneously reduce conflict due to the higher incomes and increase conflict from workers whose real wages fall.

282 Related studies include Hodler (2006); Lei and Michaels (2014); Caselli et al. (2015); Berman et al. (2017); Chiovelli et al. (2018); Sviatschi (2018); Castillo et al. (2020); de la Sierra (2020); Adhvaryu et al. (2021).

283 The government interventions studied in the literature include, for example, diplomacy, different types and locations of military interventions, weapon embargoes, reforms to property rights, development programs, service provision, community engagement programs, and food aid in conflict-prone or conflict-ridden areas, and demining, development aid, employment programs, cash transfers, and therapy sessions in post-conflict areas.

284 Studies on the more individual-level effects of conflict include, for example, Bellows and Miguel (2009); Blattman and Annan (2010); Annan et al. (2011); Akresh et al. (2012); Bauer et al. (2016); Sviatschi (2018).

in CCN, our shock did not directly lead to deaths and destruction (unlike most conflicts).[285]

Next, one of the mechanisms through which conflict affects economic development is by reducing trade and increasing economic uncertainty. While the linkages between conflict and trade have already been studied, empirical evidence is mostly cross-national (Blomberg and Hess, 2006; Martin et al., 2008b,a, 2012; Glick and Taylor, 2010; Qureshi, 2013; Rohner et al., 2013b; Seitz et al., 2015; De Sousa et al., 2018).[286] Our focus instead lies in understanding how, *within* a country, spatial proximity to a foreign conflict affects local economic development, most likely via trade disruptions as in Chiovelli et al. (2018) who study the effects of post-conflict demining on market access and local economic development. Other within-country studies such as Berman and Couttenier (2015), Berman et al. (2017) or McGuirk and Burke (2020) then exploit trade shocks (from international commodity or food prices) to study the causal effects of income on conflict *rather than* the effects of conflict on income via trade or the role of trade diversification in mitigating the local economic impact of foreign conflict.[287]

Fourthly, this work contributes to a body of literature on the drivers of city growth in poor countries. Other studies on Africa have focused on the impact of transportation investments (e.g. Storeygard, 2016; Jedwab and Moradi, 2016; Jedwab et al., 2017a; Jedwab and Storeygard, 2020), trade more generally (e.g. Glaeser, 2014; Gollin et al., 2016; Haslop et al., 2021a), demographic growth (e.g. Jedwab et al., 2017b; Jedwab and Vollrath, 2019), or climate shocks (Barrios et al., 2006; Henderson et al., 2017; Kocornik-Mina et al., 2020; Haslop et al., 2021b). To our knowledge, the literature on conflict (or terrorism) and city growth is more limited (e.g. Glaeser and Shapiro, 2002; Voigtländer and Voth, 2012; Dincecco and Onorato, 2016).[288]

Lastly, our analysis has limitations. The three countries of study are among the poorest in the world.[289] Understanding the economic effects of foreign conflict in such contexts is particularly important. However, data infrastructure and finances to collect and produce data can be challenging;[290] no consistent panel data on within-country variation in trade and migration flows, production, wages, consumer prices and amenities are available.

The rest of this paper is structured as follows. Section 4.2 provides information on the context while Section 4.3 and Section 4.4 describe the data and the empirical strategy, respectively. Sections 4.5 and 4.6 discuss the estimated average and heterogeneous effects of the Boko Haram shock as well as its effects on local (non-Boko Haram) conflict. Section 4.7 concludes.

285 Other studies of the effects of Boko Haram are mostly qualitative. Exceptions include Adelaja and George (2019); Bertoni et al. (2019). However, they study its effects in Nigeria, which complicates causal identification.

286 Martin et al. (2008b,a); Seitz et al. (2015) study the role of trade in conflict. Other studies examine the reverse relationship. Fenske and Kala (2017) study the relationship between historical African conflict and the slave trade. Emran et al. (2019) examine the long-lasting effects from temporary trade restrictions on the spatial distribution of employment and resource allocation exploiting the disrupted change in routes to the international market for two neighboring landlocked countries as the result of the the civil war in Côte d'Ivoire.

287 Berman and Couttenier (2015) find strong effects of negative income shocks (from lower international demand for a location's crops) on conflict. They find a weaker effect for more remote locations. Because remote locations are more disconnected from international markets, their shock is smaller, hence their effect is smaller. Our analysis differs because we study how trade diversification is a factor of resilience for a *given* (conflict-driven) economic shock.

288 There is, however, a literature on the economic impact of refugees on cities (e.g., Lewis and Peri, 2015; Alix-Garcia et al., 2018; Fallah et al., 2019; Rozo and Sviatschi, 2021). In our analysis, the number of refugees received by each location is a control, not the main outcome of study. Indeed, we aim to capture the economic spill-over effects of conflict via trade disruptions mostly, instead of the direct reallocation of populations from Nigeria to CCN.

289 According to the *World Economic Outlook* database of the International Monetary Fund, Niger, Chad and Cameroon are in 2021 the 8th, 10th and 38th poorest countries in the world, respectively.

290 For household survey data collection, Kilic et al. (2017) find significantly higher survey implementation cost per household in Africa compared to other regions of the world.

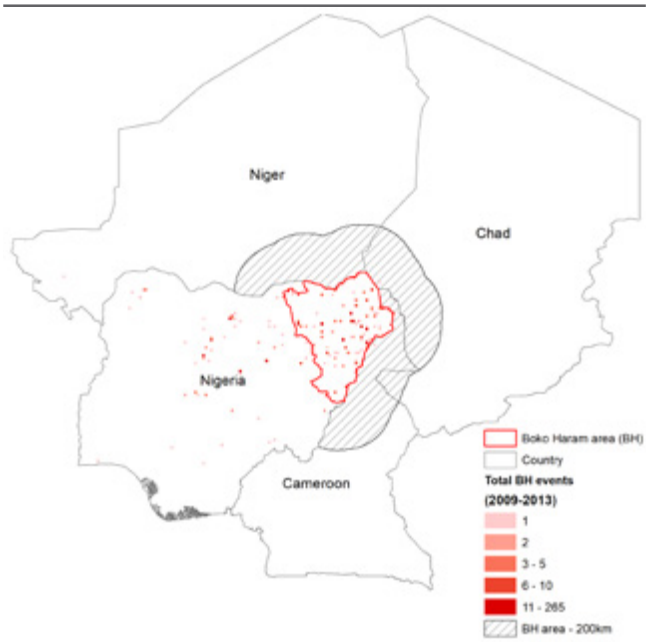
4.2 Background: Studying Boko Haram as a *Foreign* Conflict

In Nigeria. A decade-long insurgency posed by Boko Haram in Northeastern Nigeria (2009–present) is a case in point where its devastating economic and humanitarian impact has spilled over to its neighboring countries of Cameroon, Chad and Niger, killing tens of thousands of people and displacing 2.6 million globally (Tayimlong, 2020). According to the *Global Terrorism Index* of the Institute for Economics and Peace (2012–2020), Boko Haram became during our main period of study—2009–2013—the world's deadliest terrorist group, ahead of ISIL, the Taliban and Al-Shabaab. It is still the second deadliest terrorist group as of 2020.

The group was founded in 2002. Boko Haram's radicalization dates back to 2009 when state security forces killed 800 of its members, including its founder M. Yusuf (Kimenyi et al., 2014). At its peak (2015), the group seized a large swath of territories in Northeastern Nigeria, including major cities. 15 million people have been severally affected by the insurgency and the counterinsurgency efforts (Vanda Felbab-Brown, 2018). Boko Haram has continued to engage in killing and abducting civilians, forcibly marrying off women and girls to its fighters, and conducting terrorist attacks against government property, markets, refugee camps, and mosques (Omenma et al., 2020). Anecdotal evidence abounds to suggest that regional trade has been severely disrupted by the insurgency, which has resulted in repeated temporary border and road closures hampering the mobility of people, goods and services in the whole Lake Chad region (World Food Program, 2016; Opoku et al., 2017; Foyou et al., 2018; OECD/SWAC, 2020).

As seen in Map 4.1, most of the attacks between 2009 and 2013—our main period of study—were geographically concentrated in a few states in the Northeastern corner of Nigeria, essentially Borno (60 percent of all Boko Haram conflict events), but also Yobe and Adamawa. However, within Yobe, most conflict events took place south of the Yobe river. Within Adamawa, most conflict events occurred north of the Benue river. In this figure and in the rest of the paper, we thus define the core *Boko Haram area* as the area of Borno, Yobe and Adamawa that is between the Yobe river in the North (in Yobe) and the Benue river in the South (Adamawa).

Map 4.1: Boko Haram Area and the Three Countries of Study



Notes: This figure shows the main Boko Haram area (defined as the area corresponding to the states of Adamawa, Borno and Yobe that is between the Komadugu Yobe river in the Yobe and the Benue river in Adamawa, and where most Boko Haram conflict events in 2009–2013 were located). It also shows the three countries of study (Cameroon, Chad and Niger) as well as the area within these three countries that is within 200 km from the Boko Haram area.

Seen from space, the rise of Boko Haram after 2009 is strongly associated with a rapid (relative) decline in the level of economic activity in Northeastern Nigeria, as measured based on changes in night-time light intensity (NTL). As explained in the next section, this data comes from the U.S. Air Force Defense Meteorological Satellite Program (OLS-DMSP, 1992–2013). Using data for 7,761 0.1×0.1 degree grid cells (≈ 11x11km at the equator) in Nigeria for the years 2000–2013 (N = 108,654), and relying on a simple

panel difference-in-difference (panel-DiD) framework to account for cell and year effects, we find that the level of NTL decreased by 6 percent on average between 2000–2008 (pre) and 2009–2013 (post) (not shown).[291] By 2013, the correlation was -7.5 percent (Figure A4.1 shows the coefficient of the Boko Haram area dummy in each year with 2000 being the omitted year). If we restrict the panel-DiD to 3,717 cells that were lit at any point between 2000 and 2013, we get -8.5 percent and -10 percent economic decline respectively (not shown).[292] We focus on the period 2000–2013 because Boko Haram had not yet entered Cameroon, Chad and Niger. In addition, night lights data from DMSP is only available until 2013. However, Li et al. (2020) combine night light data from two satellite series—OLS-DMSP (1992–2013) and SNPP-VIIRS (2012–2018)—to generate global DMSP NTL time-series data for the whole period 1992–2018 (DMSP is used as the baseline until 2013). As seen in Figure A4.2, Boko Haram areas have experienced an even bigger relative decline in night light intensity between 2014 and 2018. Note that we use the same model as just described (N = 7,761 cells) but for the full period 2000–2018. While there are still apparent comparability issues between DMSP and VIIRS, the figure suggests that night light intensity might have decreased by as much as 60 percent by 2018.[293]

As expected, the negative correlation between the Boko Haram area dummy and economic development decreased in 2015 and 2016 when a coalition of West African forces managed to regain part of the territory that Boko Haram had captured. However, attacks by Boko Haram have since escalated and Boko Haram remains in control of large swaths of Northeastern Nigeria.

Exogeneity. *Within-Nigeria* effects are not necessarily causal given that the rise of Boko Haram might have not been independent of local socio-economic conditions. That said, the *timing* of the insurgency—2009—could be pointed as exogenous. Boko Haram was founded in 2002 and existed more or less peacefully as a sect for seven years (Cook, 2011). When in 2009 the government started investigating Boko Haram's activities and members were arrested, deadly clashes took place and the insurrection broke out. For many observers, it was surprising that the Nigerian government waited so long before cracking down on the movement. For others, it was surprising that the government finally decided to act in 2009. Thus, the government's investigation could have started anytime prior to, or after, 2009. Likewise, such investigation could have been successful without resulting in an insurrection, or the insurrection might have been swiftly contained instead of dragging on for years.[294] Finally, "control" locations outside the Boko Haram area were also affected by Nigeria losing control of almost one fifth of its territory.

Focusing on Cameroon, Chad, and Niger (henceforth "CCN"). To bypass these identification issues as well as focus on the spill-over effects of foreign conflict, we restrict our analysis to grid cells in CCN. Indeed, it was not until 2014 that Boko Haram expanded its terrorist activities outside the territory of Nigeria and into the territory of CCN (Figure 4.1 shows the trends in the number of conflict events by country for the period 2009–2018). Indeed, Boko Haram did not want to have to face four government armies. It is only when Boko Haram had no choice that it did, in particular after the Nigeria government dramatically intensified its military campaign against Boko Haram, forcing the movement to

291 The dependent variable is the log of mean light intensity (sum of lights divided by area + 1) in cell *c* in year *t*. We include cell *c* fixed effects, year *t* fixed effects, and interact the *Boko Haram area* dummy *c* (equal to one if the cell is within the Boko Haram area or if its centroid is within 10 km from the area's border) with a post-2009 (incl.) dummy *t*. The coefficient of interest is the coefficient of the interacted dummy. To account for spatial autocorrelation, standard errors are clustered at the Local Government Area (LGA; N = 721). With 7,761 cells, there are 11 cells per LGA.

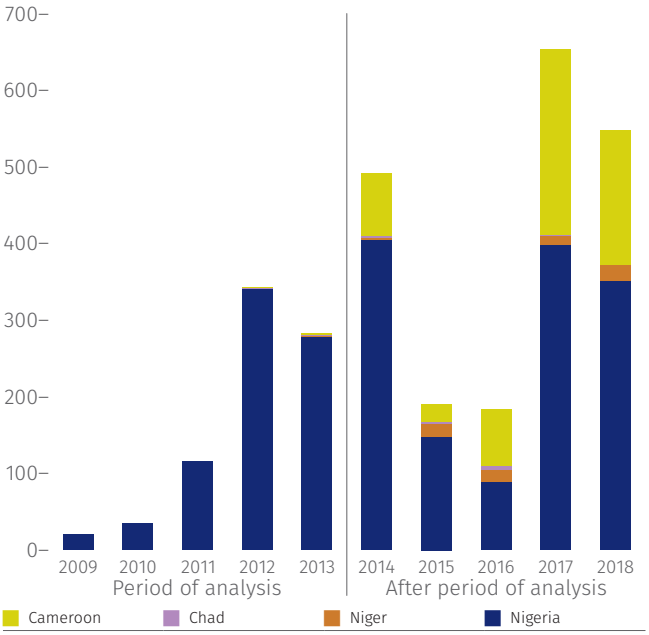
292 Also excluding 89 cells with top-coded pixels (whose maximum value is 63), we get -8.5 percent and -10.5 percent, respectively.

293 The harmonized night light data 1992–2018 is comparable by design, but harmonizing two disparate night light data sets from two different satellite series does rely on model estimates subject to error/assumptions.

294 Using the full sample and the same panel as before and interacting the Boko Haram dummy with a dummy for each year 2001–2013, we find that the negative effect of Boko Haram appears *after* 2009 (see Figure A4.1). Interestingly, we observe a slight positive effect in 2009, most likely due to the increased military presence in the area.

move some of its activities to neighboring countries. The population of the broader Lake Chad region has since been subject to an increasing number of attacks by Boko Haram, which is now linked to al-Qaeda in the Islamic Maghreb as well as the Islamic State (Enobi and Johnson-Rokosu, 2016; Daouda, 2020).

Figure 4.1: Number of Boko Haram Events, 2009–2018



Notes: This figure shows for Nigeria and each of the countries of study the number of Boko Haram conflict events in each year. As can be seen, the Boko Haram conflict was restricted to Nigeria until 2013 (incl.).

The Boko Haram insurrection represented a major economic shock at the "doorstep" of the affected regions in CCN. While the Boko Haram area of Nigeria was about twice poorer (based on mean night light intensity) than the rest of Nigeria in 2008, it was on average almost 10 percent wealthier than the whole sample of CCN (ibid.). In the region—defined as the Boko Haram area plus CCN's areas within 200 km from the Boko Haram area (see Map 4.1)—the Boko Haram area contributed more than 50 percent of the total sum of night lights in 2008. The economic shock caused by the insurrection was then amplified by the fact that the Boko Haram area offered a major trade corridor between the other three countries. The state capital of Maiduguri is the principal trade hub in Northeastern Nigeria and also between Niger and Cameroon-Chad. Anecdotal evidence suggests that trade volumes severely diminished as borders were intermittently closed and major trade routes became less accessible or even inaccessible (UNHCR and World Bank, 2016; World Food Program, 2016) as well as local markets (Blankespoor, 2021).

4.3 Sample and Main Data for Cameroon, Chad and Niger

We focus on estimating the spill-over effects of the Boko Haram-driven economic shock on the Boko Haram area's neighboring areas in CCN. Our full sample consists of 25,491 0.1*0.1 degree grid cells in CCN for the period 2000–2013 (N = 356,874). Our baseline analysis relies on a subsample of cells that were lit (NTL>0) at any point between 2000–2013, which yields a sample of 1,546 cells and a total of 21,644 observations (1,546 cells x 14 years).

Conflict Data and Boko Haram (BH) Area. We define the (core) *BH area* as the area of Borno, Yobe and Adamawa that is between the Yobe river in the North (in Yobe) and the Benue river in the South (Adamawa) (see Map 4.1). For each CCN cell, we obtain their centroid's Euclidean distance to the BH area. Our main conflict data is from the Armed Conflict Location & Event Data Project (ACLED) (Raleigh et al., 2010). We will also use data from the Uppsala Conflict Database (UCD) (University, 2020) and the Social Conflict Analysis Database (SCAD) (CCAPS, 2020).

Nighttime Lights (NTL). Since there is no reliable data that measures income or economic activities at a fine spatial level, we rely on satellite data on light emitted into space at night.[295] Satellites from the U.S. Air Force Defense Meteorological Satellite Program (DMSP) have been recording data on lights at night using their Operational Linescan System (OLS) sensor since the mid-1960s, with a global digital archive beginning in 1992. Since two satellites are recording in most years, 30 satellite-years worth of data are available for the 22-year period 1992–2013. Each 30-arcsecond pixel (≈ 1x1km) in each satellite-year contains a digital number (DN), an integer between 0 and 63, inclusive, that represents an average of lights in all nights after sunlight, moonlight, aurorae, forest fires, and clouds have been removed algorithmically, leaving mostly human settlements. This data is typically subject to the issue of top-coding. In our case, however, this is not an issue. In fact, among the 1,546 cells of our main analysis, only 11 have some top-coding. Indeed, the three countries of interest are among the poorest countries in the world. Among these 11 cells, the mean share of top-coded pixels is then only 0.05.[296] Finally, to study long-term effects we rely on the harmonized NTL data (1992–2018) from Li et al. (2020).[297]

Rural Outcomes. NTL may not perform well in capturing economic activities in rural areas which remain largely dark at night. We thus turn to other measures proxying for agricultural economic development in rural areas. The first indicator of such activities is the *Normalized Difference Vegetation Index* (NDVI)—or Greenness Index—from NASA (2020b) and we calculate its monthly mean at the grid level from 2001 to 2018. Higher values indicate denser vegetation. From European Space Agency (2017, 2019), we then obtain the share of land that can be classified as "cropland", "mosaic", "other" or "urban" (available in 2000–2018).[298]

A common agricultural practice in the region is the burning of fields (Kull and Laris, 2009; Nwaga et al., 2010). Thick layers of biomass burning aerosols, generated

295 Henderson et al. (2011) and Bruederle and Hodler (2018) demonstrate the utility of it as a local measure of GDP and human development, respectively. See Michalopoulos and Papaioannou (2013, 2014) for studies on Africa.

296 We could have used instead the radiance calibrated data from NOAA 2015 which has the advantage of not being top coded. However, this data stops in 2011 whereas DMSP-OLS stops in 2013 and we need to study 2009–2013.

297 Li et al. (2020) combine night light data from OLS-DMSP (1992–2013) and SNPP-VIIRS (2012–2018). The nighttime lights from the SNPP satellite, carrying VIIRS, series brings unprecedented information compared to the previous OLS series, including improvements such as spatial resolution (15 arc seconds or 500m) and measurement (14 bit quantization) with a wider dynamic range and lower detection limits (Elvidge et al., 2017).

298 Cropland corresponds to rain-fed, irrigated or post-flooding. Mosaic corresponds to mosaic cropland (>50 percent) or natural vegetation (tree, shrub, herbaceous cover) (<50 percent). Other corresponds to all remaining land cover.

mainly by agricultural burning during the dry season, can be detected across the Sahel region of Africa (Johnson et al., 2008). Aside from the threat to the atmospheric environment such aerosols pose, agricultural burning also causes the loss of forest system carbon, biomass and nutrient stocks due to deforestation, leading to long-term soil infertility despite achieving short-term soil fertility (Kotto-Same et al., 1997; Kanmegne, 2004). Despite the long-term harm to agricultural outcomes, impoverished farmers resort to agricultural burning to secure food and income.[299]

Following Blankespoor et al. (2021) who examine the effect of conflict on agricultural activity in the Central African Republic, we sum at the grid level the MODIS Burned Area data product (v6), which provides a burned-area estimate per 500m pixel by month (NASA, 2020a). Then, according to the main food crops for each country-crop calendar (FAO, 2020) we define each month into three seasons: (i) land preparation; (ii) sowing and growing; and (iii) harvest.

Finally, the controls and other outcomes considered in our analysis are described below.

299 70 percent of deforestation in Africa is attributed to agricultural burning, compared to 50 percent in Asia and 30 percent in Latin America (Nwaga et al., 2010). In Cameroon, about half of the annual rate of deforestation, at 0.6 percent overall, is for agricultural purposes, while the other half is attributed to logging (Gockowski et al., 2005).

4.4 Econometric Specification and Issues

We examine in a panel-DiD framework the average effect of the Boko Haram (BH) shock in CCN areas neighboring the BH area. To do so, we first investigate the geographical scope of the BH effect, i.e. how "far" into CCC a significant BH effect is observed. Second, we verify that this effect only appears in 2009, thus confirming parallel trends and the local exogeneity of the *foreign* BH shock, and also investigating how the effect varied over time during the 2009–2013 period.

Model 1. The model examines the *geographical scope* of the effect and can be formalized as follows:

$$\text{NTL}_{s,c,t} = \alpha + \sum_{d=25}^{250} \beta_d \, \text{BH}_{s,c,d} * \text{Post 2009 Dummy}_t + \lambda_s + K_{c,t} + \mathbf{X}_{s,c} B_{X,t} + \varepsilon_{s,c,t} \quad (1)$$

where s denotes the cell, c the cell's country, and t the year. NTL is the log of mean night light intensity (sum of lights divided by cell area). Since NTL can be zero in some years, we use log (mean night light intensity + 1). As discussed earlier, for our main regressions we focus on 1,546 cells with some night lights at one point in 2000–2013, thus yielding 21,644 observations in total. λ_s and $K_{c,t}$ correspond to cell fixed effects and country-year fixed effects, respectively. The main variables of interest are the interactions of the dummies $BH_{s,c,d}$ equal to one if the cell is d kilometers (in terms of simple Euclidean distance) away from the BH area in Nigeria (with d ranging from 25 km through 250 km at an increment of 25 km) multiplied by a dummy $Post\ 2009\ Dummy_t$ equal to one if the Boko Haram conflict has started, hence post-2009.

Controls. We include various important time-invariant controls $X_{s,c}$ which we interact with year fixed effects to allow their effects to vary flexibly over time. First, we control for the log of the Euclidean distances to the largest city and the capital city in the cell's country.[300] We do so because spatial patterns of economic development over time could be affected by proximity to the main economic and political centers of the country. We also control for the log of the Euclidean distance to N'Djamena, the capital and largest city of Chad. In Map 4.1, N'Djamena is located in the North-West of Chad, close to the border with Cameroon. Since N'Djamena has been growing rapidly over time, for reasons unrelated to Boko Haram, we need to avoid conflating the economic impact of Boko Haram with the rapid expansion of N'Djamena *per se*.

Due to attacks close to the border areas, Chad and Niger increased border controls as well as military presence at their borders with the North-East of Nigeria. Cameroon also increased controls at the border with Chad that is close to the BH area. This may have resulted in public expenditure—and thus night lights—in these areas, which would cause an upward bias of the effect. In other words, this would make us under-estimate how *negative* the effect is. We thus consider a dummy if the cell is a border cell and is within 50 km from the BH area.

Resource-rich areas may have also seen their NTL change over time, for example due to commodity price fluctuations. For example, there is oil production and oil refining in the three countries and Niger is also a major exporter of uranium. We create a dummy equal to one if the cell intersects with oil- or uranium-producing areas or contains an oil refinery.[301]

300 These two are different in Cameroon where the largest city is Douala, followed closely by the capital city Yaoundé.

301 We use the Petroleum Dataset version 1.0 (Lujala et al., 2007) to identify onshore oil producing areas and we digitize locations of oil refineries from national sources (e.g. Nigeria Department of Petroleum Resources, 2020). Even though both Chad and Niger have a long history with the oil industry, the only refinery in Chad, Djarmaya, opened in 2011. In Niger, the Agadem oilfield and the Soraz refinery near Zinder opened in 2011. Niger exports oil via Chad or Cameroon. U.S. Geological Survey (2006) then capture the locations of uranium producing areas near Arlit, Niger.

Finally, due to heightened insecurity in Northeastern Nigeria, areas close to the border in the three countries received Nigerian refugees but also Cameroonese, Chadian or Nigerien returnees. Some of them were accommodated by the governments and international organizations in formal refugee camps. Others moved to localities in these areas. As such, this may have induced population increases and public investments, and thus amplified night lights, in these areas. This would cause an upward bias and thus make us under-estimate the negative local effect of Boko Haram. We thus add two dummies for whether there is a refugee camp in the cell (ca. 2015) and the estimated log number of (refugees + returnees) in each cell (ca. 2015). However, the influx of refugees + returnees could also have negative economic effects, for example if social tensions are increased as a result. One could then argue that there is overcontrolling. We will thus show that results are little sensitive to the omission of these controls.[302]

Spatial Autocorrelation. To account for spatial autocorrelation, standard errors are clustered at the 3rd level administrative unit, which corresponds to *arrondissements* in Cameroon (N = 343), *sous-prefectures* in Chad (N = 336) and *communes* in Niger (N = 265).[303] For our full sample, this corresponds to 12, 33 and 40 cells per unit on average in each country respectively (areas of 1,452, 3,993 and 4,840 sq km, respectively). We use standard errors clustered using administrative units instead of Conley standard errors because, as discussed in Section 4.7, the latter are computationally intensive with many spatial units. However, we will show in the same section that results hold when clustering at a higher level or using Conley standard errors.

Model 2. The second model examines the *temporal scope* of the effect. In particular, we will find that Boko Haram only has a significant effect within 200 km from the BH area. We then slightly modify Equation (1) so as to let the effect of proximity to the Boko Haram area (within 200 km) vary each year (relative to the omitted year 2000) instead of only comparing the 2009–2013 period to the pre-2009 period. More formally, we estimate the following panel model:

$$\mathrm{NTL}_{s,c,t} = \alpha + \sum_{i=2001}^{2013} \Upsilon_i \times \mathrm{BH\ 200km}_{s,c,d} + \lambda_s + K_{c,t} + \mathbf{X}_{s,c} B_{X,t} \quad (2)$$

where the dummy variable $BH\,200km_{s,c,d}$ coded as 1 if the cell is within 200km from the BH area is interacted with year dummies Υ_i generated for each year between 2001 and 2013. Our expectation is that the effect becomes negative and statistically significant *only after* 2009.

302 Refugee camp locations come from UNHCR (2020). The estimated local numbers of refugees and internally displaced people come from Direction Régionale de l'État Civil et des Réfugiés (2016); IOM (2016); UN OCHA (2015).

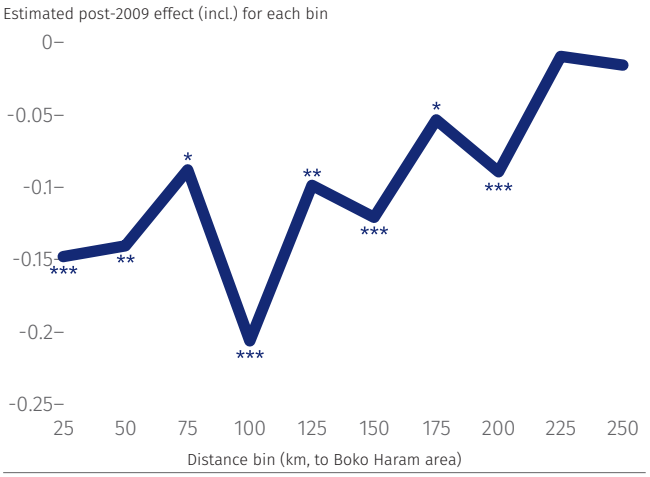
303 Administrative country boundaries come from GADM version 3.6.

4.5 Average Effects in Cameroon, Chad and Niger

4.5.1. Baseline Results

Results from the panel-DiD model (1) are shown in Figure 4.2. There is a significant effect of Boko Haram in the range between 25 (0–25) and 200 (175–200) km. The average effect within 50 km (across the 25 and 50 bins) is -0.15 (p < 0:01), implying that the rise of Boko Haram reduces NTL by 15 percent. The average effect for 50-100 km (across the 75 and 100 bins), 100-150 km (across the 100 and 125 bins) and 150–200 km (across the 175 and 200 bins) is -15, -11 and -7 percent (p < 0:01), respectively. The average effect within 200 km is then -0.12 (p < 0:01), implying an average decrease of 12 percent. For the sake of simplicity, in the rest of the analysis we focus on a simple 0–200 km dummy, thus estimating an average effects across all affected bins.

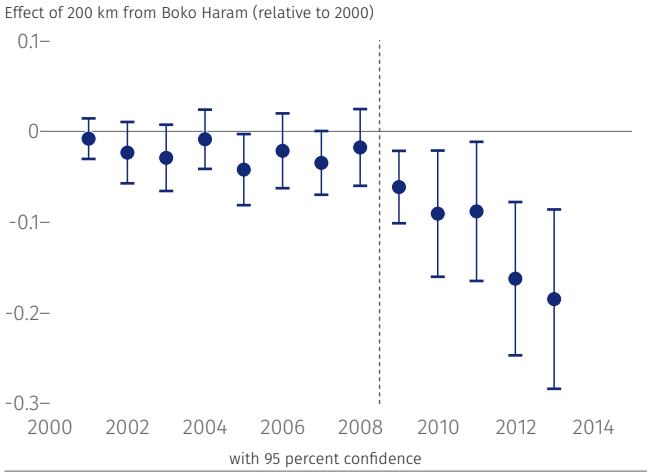
Figure 4.2: Post-2009 (Incl.) Boko Haram Effect by Distance to the Boko Haram Area



Notes: The figure shows the post-2009 (incl.) Boko Haram effect for each distance (to the Boko Haram area) bin. 25 corresponds to 0–25 km, 50 corresponds to 25–50 km, ..., and 250 corresponds to 225–250 km. See Equation (1) for details on the specification. See Appendix for data sources. * p<0.10, ** p<0.05, *** p<0.01.

We find evidence that the assumptions of parallel trends and local exogeneity of the BH shock hold. As seen in Figure 4.3, when using the model of Eq. (2) no effect is observed before 2009, a small effect is observed in 2009, and the effect decreases after that. This is expected given the rapid intensification of the Boko Haram insurgency after 2009. By 2013, the effect is about -0.20, so cells "close" to the BH area have lost 20 percent of their level of economic activity on average.

Figure 4.3: Yearly Effect of Proximity to the Boko Haram Area (0–200 km)



Notes: The figure shows the yearly effect (relative to the year 2000) of a dummy equal to one if the cell is within 200 km from the Boko Haram area. See Equation 2 for details on the specification. * p<0.10, ** p<0.05, *** p<0.01.

If we use same model but further separate the BH 0-200 km dummy into 0–50, 50–100, 100–150 and 150–200 km dummies, we find that Boko Haram has no effect before 2009 in the four groups of cells. The effect by 2013 is then about -15, -20, -20 and -30 percent (p < 0:01), respectively (see Figure A4.3). Aggregating some of these effects, cells within 100 km have lost almost 25 percent while the cells farther away (but still within the 200 km window) have lost about 15 percent. In the rest of the analysis, we will also sometimes distinguish 0–100 and 100–200 km.

Finally, we use the panel-DiD model of eq. (1) and the harmonized NTL data from Li et al. (2020) to study the long-term effects of the shock. There are several caveats with this analysis. First of all, there may still be comparability issues between DMSP (used for the 2000–2013 period) and VIIRS (2014–2018) in the data of Li et

al. (2020). Second, Boko Haram had attacked Cameroon by 2014 and Chad and Niger by 2015 and there may have been local and spill-over effects of these attacks. However, only 60 cells were ever affected in CCN. To attempt to study the long-term effects of foreign conflict, we exclude the 60 cells as well as 166 cells within 50 km of these 60 cells. We also control for the log of the Euclidean distance to a CCN Boko Haram event in year *t*.

As seen in Figure A4.4, the negative effect of Boko Haram increased in magnitude over time, reaching -35 percent by 2015 and -50 percent by 2018. We see some recovery effects in 2016 when West African troops managed in 2015 to regain some of the territory captured by Boko Haram in Nigeria, another implicit test of our identification strategy. We thus see positive spill-over effects of a successful foreign counter-insurgency campaign. Next, the high standard errors for the VIIRS observations likely reflect the fact that the assumptions made by Li et al. (2020) to recreate consistent NTL for the whole period also introduced a significant amount of noise. Lastly, we may not be capturing a long-term effect *per se* as the conflict never ended.[304]

Overall, we find very strong negative local effects of foreign conflict. The question now is which sectors, and thus locations, foreign conflict disproportionately impacts and why.

4.5.2 Foreign Conflict as a Trade Shock Disproportionately Impacting Cities?

In this section, we examine whether the foreign conflict shock disproportionately impacted trade-reliant cities, mostly due to trade disruptions. To do so, we first show using the night lights data and other data on rural economic development that urban areas were far more impacted than rural areas. Next, we argue that curfews, the in-migration of refugees and/or the outmigration of residents were not driving the results. Finally, we do not find evidence for spill-over effects on conflict. Thus, incomes did not decrease in the border regions because conflict factors (e.g., armies and weapons) moved from the BH area to these regions. Ultimately, we believe that conflict in the BH reduced CCN's trade with Nigeria but also trade between the regions of Cameroon-Chad and Niger that historically used the BH area as a trade corridor.

4.5.2.1 Other Results on Night Lights and Rural Economic Outcomes

Night lights. Our analysis thus far focused on the sample of cells that were ever lit at some point between 2000 and 2013. We now consider other samples of cells.

Table 4.1: Post-2009 Effect of Proximity to the Boko Haram Area (0–200 km), Night Lights

Dependent Variable:	*Col. (1)–(3) and (5): Log (Mean Night Light Intensity + 1) in Year t* *Col. (4): Dummy if Mean Night Light Intensity in Year t > 0*				
Sample:	*Intensive (1)*	*All (2)*	*Extensive (3)*	*Extensive (4)*	*Pure Intensive (5)*
BH 200 Km * Post-2009	-0.097***	-0.007**	-0.001	-0.004	-0.143***
	[0.027]	[0.003]	[0.001]	[0.003]	[0.046]
Cell FE, Country-Year FE	Y	Y	Y	Y	Y
Year FE*Controls	Y	Y	Y	Y	Y
Observations	21,644	356,874	348,470	373,227	7,835
Adjusted R-squared	0.89	0.89	0.21	0.27	0.93

Notes: SEs clustered at the 3rd-level administrative unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

304 The data from Li et al. (2020) generate more consistent results between the pre- and post-2013 periods for CCN than for Nigeria. Indeed, Li et al. (2020) explain that the harmonization of the DMSP and VIIRS series might work differently for locations with a level of night lights below vs. above 30. Nigeria has locations both below and above 30 whereas there are fewer such values in CCN. As such, harmonization should be less problematical there.

Table 4.1 shows the results for: i) the "intensive" margin sample, i.e. only the cells that were ever lit between 2000 and 2013 (Col. 1); ii) all observations (Col. 2); iii) the "extensive" margin sample, which excludes cell-years with night light intensity > 0 in t-1 (Col. 3); iv) the "extensive" margin sample but with a simple dummy coded 1 if light intensity is higher than 0 in year t (Col. 4); and v) the "pure intensive" margin sample that consist of cell-years for which light intensity > 0 in both t-1 and t (Col. 5).

The negative effects of foreign conflict are particularly pronounced in urban areas (as reflected in cells that are lit between 2000 and 2013). In the "intensive" and "pure intensive" samples (Cols. 1 and 5), the average effects are -10 percent and -14 percent both significant at the 0.01 level, respectively, whereas these effects are smaller in the full sample (Col. 2) and insignificant at the extensive margin (Cols. 3 and 4).[305] More generally, the intensive margin effect of -0.097*** in Col. 1 represents about 47 percent of the mean in the sample (which is 0.47) whereas the extensive margin effect of -0.004 in Col. 4 represents only 5 percent of the mean in the sample (0.07).

We thus do not find any effect of foreign conflict on the likelihood that non-lit cells become lit, a proxy for rural economic development. Villages and small towns close to the BH area are thus not less likely to generate enough luminosity picked up by the satellites. These results could suggest that the geographical scope of the spill-over effects is limited to more urban areas, likely because these urban settlements rely more extensively on regional trade with, or through, the BH area than their rural counterparts (more on this later).

However, one caveat is that NTL may not measure well rural growth or decline, even when focusing on the extensive margin only. Thus, to better examine rural effects, we study other reasonable proxies for rural economic activities: greenness, land use, and agricultural burning.

The effects of foreign conflicts on rural economic development are theoretically ambiguous. Rural areas are possibly isolated from such shocks if they do not trade with foreign areas. However, if they sell their agricultural products to the foreign area, the level of demand decreases. Furthermore, if urban areas are negatively impacted by reduced trade with the foreign area, this could in turn impact the demand for agricultural products in rural areas. In a context of high population growth, the latter mechanisms would lead to slower rates of land expansion.

Alternatively, if urban areas import rural products from the foreign area, insecurity may lead urban areas to demand local rural products instead. Reduced economic opportunities in urban areas trading with the foreign area could also lead urban residents to seek economic opportunities in the rural sector (in the region, it is common for urban residents to have farming relatives in surrounding rural areas). In such cases, we might observe faster land expansion.

Greenness. The measures of greenness, land use and burned area are available at the grid cell level for 23,945 cells *without* night lights at any point between 2000 and 2013, which correspond to more rural areas.[306] In terms of the Greenness index, data is available on the monthly basis. When studying monthly patterns, we find that greenness peaks in August in Niger and Chad—at the height of the rainy season—and is high in Cameroon around May (the light rainy season) and September (the heavy rainy season). Once one accounts for country-month effects, greenness could capture land expansion or land abandonment and thus proxy for rural growth.

For greenness (available in 2001–2013), the model is the same panel-DiD model as before except the dependent variable is the log of (mean greenness + 1) in the cell s in

305 We find similar non-effects at the extensive margin when separating 0–100 km and 100–200 km (not shown).
306 Results are similar if we keep all cells including those cells that are ever lit between 2000 and 2013 (not shown).

Table 4.2: Post-2009 Effect of Proximity to the Boko Haram Area (0–200 km), Rural Outcomes

Dep. Var.:	*LogMean Green. t*	*Share Crop+ Mos*	*Col. (3)–(4) and (6)–(9): Log (Agricultural Burning + 1) in t Col. (5): Dummy if Agricultural Burning > 0 in t*						
Sample:	*All (1)*	*All (2)*	*All (3)*	*Extensive (4)*	*Intensive (5)*	*Pure Prep. (6)*	*Land Growing (7)*	*Sowing (8)*	*Harvest (9)*
BH 200 km * Post-09	-0.000	-0.001	0.042**	0.007*	0.007	0.047	0.001	0.005*	0.070**
	[0.001]	[0.001]	[0.017]	[0.004]	[0.006]	[0.035]	[0.016]	[0.003]	[0.027]
Cell FE, Cntry-Yr FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE*Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	311,285	311,285	232,040	232,040	61,496	311,285	311,285	311,285	311,285
Adjusted R-squared	1.00	1.00	0.85	0.40	0.38	0.71	0.77	0.31	0.79

Notes: SEs clustered at the 3rd-level administrative unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

year *t* (mean = 0.31).[307] As can be seen in Col. (1) of Table 4.2, we find no effect of Boko Haram on greenness (the point estimate only represents 5 percent of the mean in the sample that is 0.31).[308]

Land Use. We know the share of land that can be classified as either "cropland" or "mosaic cropland" (at least 50 percent cropland) for the full period 2000–2013 (mean = 0.09). As seen in Col. (2), we also find no effect of Boko Haram on land intensification or de-intensification (the point estimate only represents 1 percent of the mean in the sample that is 0.09).[309]

Agricultural Burning. When studying monthly patterns in agricultural burning, we find that it peaks in November-December when the harvest season ends. This type of agricultural burning corresponds to the practice of stubble burning, where farmers set fire to the straw stubble that remains after crops have been harvested. Agricultural burning is then observed until April–May, at the end of the land preparation season. For land preparation (which includes the preparation of new land that was not agricultural before), slash-and-burn is common there. We thus investigate how agricultural burning (available in 2001–2013) varies with the rise of Boko Haram, depending on the season: "harvest", "land preparation" and "sowing-growing".[310] Since agricultural burning area can be equal to 0, we use log(burning + 1) as the dependent variable. As we did for NTL, we explore different margins (intensive, extensive, etc.) in Table 4.2 Col. 3–9.

In Col. 3, which includes all cell-years, we find a positive and significant effect of 0.042*.** It is however smaller than what was found for night lights. In particular, the point estimate represents 20 percent of the mean in the sample (20.4) against 47 percent for night lights.

The burning effect is driven by both extensive margin (Col. 4) and pure intensive margin (Col. 6) effects. More precisely, in Cols. 4 and 5, we restrict the sample to cell-years whose burning in *t*-1 is zero. In Col. 4, the outcome is log(burning + 1) in *t* whereas in Col. 5 it is a dummy equal to one if burning > zero. The effect on the

307 Greenness has negative values. To use logs, we first shift all observations by the absolute value of the minimum value in the data (so that the new minimum value is 0) and then add +1. Also, since greenness is not bottom-coded we do not need to distinguish the intensive and extensive margins as we did for NTL.

308 For the sake of simplicity, we use mean greenness averaged across the 12 months of a given year. We obtain the same non-results if we regress for each cell-year-month greenness on country-month dummies and use as our measure the log of the average of the residuals (not shown). There also no effects for 0–100 vs. 100–200 km (ibid.).

309 The coefficients are not significantly different between 0–100 km and 100–200 km (not shown).

310 We rely on crop calendars from FAO GIEWS. "Harvest": October–November in Cameroon; September–November in Niger; September–December in Chad. "Land preparation": December–April in Cameroon; December–May in Niger; January–April in Chad. "Sowing-growing": May–September in Cameroon; June–August in Niger and Chad.

dummy is small and not significant (Col. 5). However, the effect on log(burning + 1) is positive and significant (0.007*). Thus, BH resulted in more burning amongst those cells without any burning in the previous year. In Col. 6, we focus on the pure intensive margin effect for cell-years with burning > 0 in both *t*-1 and *t*. The effect is not significant but seven times higher than for the extensive margin (0.047, or about 5 percent).

Burning, while traditionally used, is not a sustainable farming practice as it depletes the nutrients in the soil. Results suggest that agriculture is little mechanized (i.e., more traditional) in these areas, and that farmers are willing to increase short-term incomes at the expense of future incomes. Thus, farming households (and their possibly more urban-based members) may have become more present-biased in the face of the shock. Note that these results hold if we exclude border cells within 50 km from the Boko Haram area in case the measures of agricultural burning pick up fires related to destruction caused by Boko Haram itself (not shown).

Finally, in Cols. 7–9 which disaggregate the results by different seasons, we show the effects are driven mainly by the end of the harvest period. This finding implies that burning was not a result of preparing new land that had not been exploited before (Col. 7) but came from increasing income as soon as the harvest season was over (Col. 9). This practice is particularly damaging in the long run since soils cannot recover at all. Also, the fact that it is at the end of the harvest season indicates that the observed effects are for parcels that were already exploited the year before, not new parcels (in line with the non-results for greenness and land use).[311]

Overall, we find no effect on rural lights or land expansion. Thus, the positive effects of the shock on rural growth must have somewhat compensated its negative effects. For example, even if the export of rural products to Nigeria decreased, there was also less competition from rural products coming from Nigeria. However, even if land use did not change overall, it could still be that the shock very negatively impacted some farming communities. As their members likely live close to the subsistence level, they found ways to increase short-run incomes even if it meant borrowing against the future. Overall, while some rural areas were negatively impacted, the rural sector does not appear to have been driving the economic crisis observed in the region, hence our characterization of the Boko Haram-led economic shock as an "urban" shock.

4.5.2.2 Income Shocks, Migration, and Urban Land Expansion

Curfews. First of all, the reduction in night lights was not due to curfews. While curfews were indeed imposed in some parts of Northeastern Nigeria, especially around the city of Maiduguri, there were no curfews occurring in CCN before Boko Haram actually entered these countries.

Refugees and Returnees. Second, we could imagine that the inflows of refugees and returnees had negative economic effects on host communities in the border regions. Such inflows could also have had positive effects if they generated economic activity and/or led to local increases in public expenditure. The results reported so far are conditional on various controls for the location of refugee camps and the (log) number of returnees in each cell c. 2015 (all interacted with year fixed effects to allow their effects to vary over time). Our baseline intensive margin effect is -0.097*** (Col. 1 of Table 4.1). If we omit the refugees/returnees controls, we obtain a slightly more negative effect of -0.103***. If anything, this suggests that the inflows of refugees/returnees had, on net, slightly positive, not negative, local economic effects.[312]

311 Throughout (Cols. (3)–(9)), the effects are stronger for 0–100 km than for 100–200 km (not shown).

312 Results are similar whether we omit the "refugees" controls only or the "returnees" controls only (not shown). As expected, cross-sectional regressions for the 1,546 cells confirm that the border regions had more refugee camps c. 2015 (Ibid.). However, conditional on the baseline controls, they did not receive more returnees c. 2015 (Ibid.).

Population Outflows due to Heightened Insecurity. We could also imagine that populations afraid of the rise of Boko Haram in Nigeria left the border regions, thus causing reductions in luminosity. Indeed, changes in night light intensity (sum of night lights divided by area) may reflect both changes in nighttime lights *per capita* (in other words, per capita incomes) and population changes (net migration). Of course, the two subcomponents are mechanically correlated. If incomes decrease, local residents will more likely out migrate to other areas and non-local residents will less likely migrate in. We now discuss the respective contributions of each channel, which allows us to discuss the potential role of outmigration.

Suppose that income (NTL) per capita increases in a cell relative to other cells. Under this hypothetical situation, people migrate in and population density in settled areas initially increase (built-up area is fixed in the short-run as construction takes time). As a result, housing prices increase. Housing supply eventually responds. In areas where land is relatively cheap and construction technology not so advanced, housing supply is likely to respond by using more land, not building taller structures. Hence, the cell's built-up share should eventually increase. As urban land expands, the population density in settled areas that initially increased redecreases. As population increases, NTL per capita may also decrease after initially increasing if increased labor supply reduces wages. However, the levels of income per capita and population density are likely to remain higher than they were before the initial per capita income increase. In this case, cell growth may be captured by a combination of NTL per capita, population density (population divided by built-up areas) and land expansion (built-up area divided by total area).

Now, when income (NTL) per capita decreases in a given location to another location, people out-migrate (or migrate-in less). As a result, population density in settled areas decreases. However, housing is durable (Glaeser and Gyourko, 2005). Thus, if people outmigrate, housing prices decrease, incentivizing them to stay. Individuals more sensitive to lower housing prices are more likely to stay, thereby resulting in a greater proportion of poorer individuals. As housing supply is now relatively higher (compared to demand), there is less construction. Since construction takes the form of land expansion in poor countries (Jedwab et al., 2020, 2021), one prediction could be that there is less land expansion in these areas as a result of the shock. However, the effect should not be instantaneous since the construction sector often reacts with some temporal lag. In addition, people may wait for a few years before deciding whether to outmigrate and thus just "weather" the shock. In particular, observers initially did not expect the BH insurrection to last long as Nigeria was the most developed country in West Africa. The residents of Cameroon, Chad and Niger also probably expected the BH shock to be temporary.

To conclude, with the negative BH-led economic shock, we may expect a strong effect on NTL per capita that is only weakly associated with an effect on population density and land expansion. In that case, most of the effect on NTL should come from changes in NTL per capita.

To better assess the plausibility of the previous hypothesis, in Table 4.3 we focus on urban population outcomes by leveraging data from the *Global Human Settlements (GHS)* database. GHS use satellite data to obtain for each cell built-up land area over time, more precisely c. 1975, 1990, 2000 and 2013/14, which nicely coincides with the end of our period of study.[313] Furthermore, GHS reconstructs city populations c. 1975, 1990, 2000 and 2015, using urban population levels at a relatively low administrative level circa these years and then allocating the population within these administrative areas depending on the distribution of built-up area.[314] However, the population levels reported by GHS may

313 Built-up area is from GHS Builtup (Corbane et al., 2019). See https://ghsl.jrc.ec.europa.eu/ for details.
314 Note that the GHS database focuses on urban agglomerations with more than 50,000 inhabitants c. 2015.

Table 4.3: Post-2009 Effect of Proximity to the Boko Haram Area (0–200 km), Urban Outcomes

Dependent Variable:	***Log (Mean Light Intensity + 1) t***				***LogUrb. Pop. t***	***(6), (8)–(9): Log (Built-Up Area + 1) t (7): Dummy if Built-Up Area t > 0***			
Sample:	***All (1)***	***All (2)***	***Niger (3)***	***Niger (4)***	***Niger (5)***	***All (6)***	***Extensive (7)***	***Extensive (8)***	***Intensive (9)***
BH 200 km * Post-2009	-0.18***	-0.17***	-0.24***	-0.24***	0.07	0.17	-0.05	-0.49	0.11
	[0.06]	[0.06]	[0.07]	[0.07]	[0.19]	[0.46]	[0.10]	[0.86]	[0.19]
Log(BuiltUp Area/ Area+1)*t*		9.13***							
		[1.85]							
Log(Urb. Pop./Area+1)*t*				0.023					
				[0.015]					
Cell FE, Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE*Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,638	4,638	1,689	1,689	1,165	4,638	2,237	2,237	2,401

Notes: SEs clustered at the 3rd-level administrative unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

not be reliable in our context because of the lack of census data. In Niger, there were censuses in 2001 and 2012, so their population level c. 2015 actually reflects 2012. For Chad, the last two censuses were 1993 and 2009. For Cameroon, these were 1988 and 2005. As such, the reported population levels for 2015 likely measure populations *pre*-Boko Haram. Thus, in this analysis, we report the results based on built-up land area or the results based on urban population sizes but for Niger only.

In Table 4.3 Cols. 1–4, we use log(NTL + 1) for the years 1992—which we call "1990"—2000 and 2013. This is the same panel-DiD regression (eq. (1)) as before but we exclude the years in between. Note that we use data from 1990, 2000, and 2013 to mimic the structure of the GHS data. First, in Cols. 1–3, we focus on the 1,546 cells with NTL > 0 at any point in 2000–2013 × 3 years, hence N = 4,638. The sample of 1,546 cells is the sample where we showed strong negative effects on NTL. More precisely, according to Figure 4.2, we had an effect of almost -0.20 (hence -20 percent) by 2013. In Col. 1, we use the same BH 200 Km dummy × post-2009 (in this case, the year "2013", hence 2013/14) and obtain -0.18 (p < 0:01), hence the same result.

In Col. 2, we control for the log of built-up density (or urban built-up area divided by total area) since it is available for all cells in 1990–2013. The effect is only slightly lower, at -0.17 (p < 0:01), hence -17 percent. Thus, assuming built-up density captures the effects of both built-up density and population density in settled areas—thus, population—almost all of the effect of the shock on night light intensity must be due to the income shock (i.e., NTL per capita).[315]

In Cols. 3–4, we focus on Niger, the only country with city population data post-2009. In Col. 3, we run the same regression as in Col. 1 for Niger only. The estimated effect is -0.24 (p < 0:01). Thus, the negative effect on NTL appears to have been stronger in Niger than in Cameroon/Chad. However, if we control for log urban population density (total city population divided by area) in the cell, we observe the same effect. Thus, almost all of the effect of the shock on night light intensity must be due to reductions in income per capita (i.e., NTL per capita).[316] Relatedly, if we use log(total city population) as the dependent variable, thus comparing the population size of existing urban agglomerations over time, we also find no effect of Boko Haram post-2009 (Col. 5).

315 Note that we use the log of (urban built-up area divided by total area +1). Indeed, some cells with NTL > 0 have an urban built-up area of 0 according to GHS. We thus verify that these cells also have very low levels of NTL.

316 Since some cells have no urban population according to GHS, we use log(total city population area + 1).

Alternatively, we study if built-up area changed due to the shock. Since structures are durable, built-up areas did not shrink. However, the shock may slowed down urban land expansion. We thus study log(built-up area + 1) for the years 1990, 2000 and 2013.[317] In Col. 4, we focus on the same 1,546 cells but study how log built-up area grew slower with the shock. Given that structures are durable, we control for log (built-up area +1) in *t*-1 interacted with year fixed effects.[318]

As seen in Col. 6, the coefficient is positive and not significant. Thus, the main negative effect on night light intensity is not due to urban land expansion slowing down. Next, in Cols. 7 and 8, we study the extensive margin and focus on cell-years whose built-up area in *t*-1 is zero (we no longer need to control for past built-up area). In Col. 7, the dependent variable is a dummy if the cell has some built-up area in *t*. In Col. 8, it is the log of (built-up area +1). The effect is negative but insignificant, which leads us to conclude that while urban land expansion could have slowed down, reductions in income (NTL) per capita drove the results.

Finally, in Col. 9, we focus on the pure intensive margin, keeping cell-years whose built-up area in *t*-1 is higher than 0 (we control for past built-up area). The positive effect suggests accelerated urban land expansion in cells where there were already built-up areas. Since the overall effect (Col. 6) is positive, the intensive margin effects must have been stronger than the extensive margin effects. This may be counter-intuitive since the coefficient in Col. 9 is lower in absolute value than the coefficient in Col. 8. However, the coefficient captures percentage changes, so the absolute effects depend on the initial levels of built-up area in cells with built-up areas in *t*-1.

Overall, we find that the negative effects of foreign conflict on local economic development are driven by per capita incomes falling, not migration. If anything, affected individuals appeared to have stayed in these areas despite the massive income shock, one plausible explanation being the fact that the shock was seen as temporary (even it was not in the end).

4.5.2.3 Foreign Conflict, Local Conflict, and Local Economic Development

Foreign conflict should have direct economic effects. However, foreign conflict can also have a direct impact on local conflict, for example by increasing the supply of weapons and trained mercenaries in the region. Alternatively, foreign conflict, by reducing local incomes, increases the likelihood of local conflict. In that case, we still capture a direct economic effect of foreign conflict but the effect is magnified by a local conflict effect. While possible, we show below that the Boko Haram shock did not increase the likelihood of local conflict in CCN. Consequently, the effect estimated so far are the pure direct economic effects of foreign conflict.

For the years 2000–2013, we employ the same panel-DiD model as before, but we now use measures of conflict as the dependent variable. In Panel A of Table 4.4, the dependent variable is a dummy equal to one if a conflict event unrelated to Boko Haram occurred in the cell in year *t*. In Panel B, it is the number of non-Boko Haram conflict events in the cell in year *t* (unlogged because there are few events in a same cell in each year). Next, for each conflict database, we study the effect for all cells first and then for the intensive sample (where NTL > 0 at any point in 2000–2013) and the extensive sample separately. Finally, ACLED and UCD focus on armed

317 Since most cells have the same area, log built-up area is similar to the log of the share of built-up areas.

318 This allows for the durability effect to vary over time, for example due to changing construction technologies. Adding a lag of the dependent variable in a panel model introduces a dynamic panel bias (Nickell, 1981) so these results should be taken with caution. However, we do not need these controls when studying the extensive margin.

Table 4.4: Effects of Boko Haram on Domestic Conflict, Various Databases, 2000–2013

Conflict Database:	*ACLED (Armed Conflict)*			*Uppsala (Armed Conflict)*			*SCAD (Social Conflict)*		
Sample:	*All (1)*	*Intensive (2)*	*Extensive (3)*	*All (4)*	*Intensive (5)*	*Extensive (6)*	*All (7)*	*Intensive (8)*	*Extensive (9)*
Panel A:	*Dep. Var.: Dummy if Non-Boko Haram Conflict Event in the Cell in Year t*								
BH 200Km * Post-09	0.0002	0.0047	-0.0002	0.0003	0.0035	0.0000	0.0005	0.0028	0.0002
	[0.0004]	[0.0042]	[0.0003]	[0.0002]	[0.0025]	[0.0001]	[0.0005]	[0.0046]	[0.0002]
Mean	0.0011	0.0106	0.0004	0.0004	0.0028	0.0002	0.0005	0.0047	0.0002
Panel B:	*Dep. Var.: Number of Non-Boko Haram Conflict Events in the Cell in Year t*								
BH 200Km * Post-09	0.0024	0.0219	0.0000	0.0009	0.0092	-0.0000	0.0010	0.0055	0.0003
	[0.0022]	[0.0223]	[0.0006]	[0.0007]	[0.0072]	[0.0001]	[0.0007]	[0.0070]	[0.0002]
Mean	0.0011	0.0106	0.0004	0.0004	0.0028	0.0002	0.0005	0.0047	0.0002
Cell FE, Cntry-Yr FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Yr FE*Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	356,874	21,644	335,230	356,874	21,644	335,230	356,874	21,644	335,230

Notes: SEs clustered at the 3rd-level admin. unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

conflict (Cols. (1)–(6)) whereas SCAD focuses on (not necessarily armed) social conflict ((7)–(9)).[319]

As seen, none of our variables is significant. Therefore, the likelihood of domestic conflict did not increase significantly, which suggests that any economic impact of BH on neighboring areas in CCN must have been due to reduced trade, not a direct effect of BH on conflict supply factors. Likewise, the effect of the BH-led economic shock was not reinforced by an indirect feedback effect in which poverty led to conflict, which in turn further caused poverty.[320]

In addition, the effect of BH on conflict appears stronger (but is still not significant) in the more urban intensive sample than in the more rural extensive sample. Indeed, more urban areas have been disproportionately hit by the BH-led economic shock.

We then obtain similar non-results if, for the full (intensive + extensive) sample, we: (i) study a composite index based on the number of conflict events plus 0.5 × the number of fatalities, thus giving more weight to more lethal conflict events (note that 0.5 is arbitrary); and (ii) examine specific types of conflict. The results when using conflict data from ACLED, UCD and SCAD can be seen in Tables A4.1, A4.2 and A4.3, respectively.[321] We then find similar non-results if we focus on the intensive sample only (not shown, but available upon request).

Next, CCN's governments increased military presence in the region. As such, domestic conflict might have been prevented in areas close to BH. Yet, if increased military presence came from redeployment, which is plausible given the time it takes to expand an army, it might have increased conflict in areas farther away from BH. However, we do not observe negative effects. In addition, we find similar non-results as in Table 4.4

319 The total number of conflict events that took place in 2000–2013 is 900 in ACLED, 221 in UCD, and 276 in SCAD. The discrepancy between ACLED, UCD and SCAD could be due to them capturing distinct aspects of conflict or the way they assign the events to specific locations. However, results hold if we combine the three databases (not shown).

320 We also do not find stronger effects for 0–100 km than for 100–200 km (not shown, but available upon request).

321 For ACLED, we consider battles, violence against civilians, protests/riots, non-violent strategic developments, and explosions/remote violence. For UCD, we consider state violence (government forces are involved), non-state violence (none of the warring parties is a government), and one-sided violence (armed force is used against civilians). For SCAD, we consider demonstrations, riots, strikes, and violence. Note that the significant effect for UCD and one-sided violence (A2) is due to conflict ending in Eastern Chad in 2008, so not Boko Haram in Western Chad.

if we drop cells located within 50 km from a military or gendarmerie headquarter c. 2020 (Table A4.4). In francophone countries the gendarmerie is a paramilitary organization with law enforcement duties among the civilian population and gendarmes often intervene where there is a national emergency crisis.[322]

Lastly, one way to interpret these non-results is that reduced urban incomes (especially related to a trade shock) does not automatically lead to more conflict. Otherwise, the average effects would have been significant. Thus, foreign conflict does not always beget domestic conflict.

A body of literature has shown that negative income shocks, most often related to weather related shocks, lead to increased instances of conflicts (Berman and Couttenier, 2015; Harari and Ferrara, 2018). Hegre and Sambanis (2006) also show that conflict begets more conflict. Lower incomes are often one of the main channels explaining spillover effects. Indeed, with lower incomes, the cost of hiring soldiers is lower (i.e. the opportunity cost of conflict labor is lower) (Harari and Ferrara, 2018). The existing literature relies on shocks that disproportionately affect the agricultural sector and thus rural areas. However, our shock disproportionately impacts urban areas, and urban areas might be more negatively impacted by conflict than agriculture. Indeed, urban production relies more on trade and thus security whereas rural production relies more on fixed factors of production such as land. Subsequently, rural production should be less affected by conflict than urban production. As such, there could be reduced economic incentives to engage in conflict when the income shock originates in urban areas.

To summarize, while it is possible that the shock led to increased conflict in some areas of CCN, *on average* we do not find significant effects of Boko Haram activities in Nigeria on domestic conflict. We interpret this non-result as confirming that the very negative economic impact of Boko Haram on neighboring areas in CCN was driven by reduced trade in the region.

322 Military headquarters include the headquarters of military regions (5–8 depending on the country). Gendarmerie headquarters include the headquarters of "compagnies" or "legions de gendarmerie" (15–23). Sources used include administrative sources, security reports, newspaper articles, and Wikipedia. There is no data for the pre-2009 period.

4.6 Heterogeneous Effects for Cameroon, Chad and Niger

Now that we have identified the "nature" of the Boko Haram shock for neighboring areas in CCN, we can investigate the factors that accentuated or mitigated these spillovers of foreign conflict.

As seen in Figure 4.3, the 95 percent confidence interval values of the estimated effects vary significantly, from -0.10 to -0.30 percent in 2013. For the year 2018, the effects varied by between -30 and -80 percent (Figure A4.4). However, given issues when harmonizing the DMSP and VIIRS series, these values respectively represent upper- and lower-bound values of the 95 percent confidence intervals.

Likewise, the effect varies across the three countries. In particular, we use the same panel-DiD model as before but interact the "200 km Boko Haram x post-2009" dummy with three dummies for whether the cell's country is Cameroon, Chad or Niger. For the year 2013 and relative to the year 2008, we find an effect of about -5 percent (n.s.), -20 percent (***) and -25 percent (**), respectively (not shown, but available upon request). Thus, in Cameroon, no significant effect is found on average. In the three countries, we then observe marked heterogeneity in the effects, as suggested by the wide confidence intervals (-0.13/0.03, -0.36/-0.10 and -0.47/-0.04, respectively).[323]

Thus, the disruption effects of Boko Haram were very heterogeneous. However, for a given shock and country, it does not answer the question of which locations "suffered" more vis-á-vis others. Conversely, which locations were ultimately more resilient to the negative effects of the shock? To answer these questions, we use the same panel-DiD model as before but add the interaction between the 200 km Boko Haram dummy and cell-specific characteristics defined c. 2009 or before. Lastly, given the country-year fixed effects we compare cells *within* the same country.

4.6.1 Heterogeneity with Respect to Initial Economic Conditions

We first explore how the effects vary depending on initial economic conditions, i.e. night light intensity in 2008 (Boko Haram rose in 2009). For each cell, we create a dummy equal to one if the cell's night light value in 2008 is below the 10th or 25th percentile (i.e., the cell is "less" developed) or above the 75th or 90th percentile (i.e., the cell is "more" developed) in the cell's country. In a triple-difference framework, we then interact the "200 km Boko Haram x post-2009" dummy with the dummy to see if the effect is stronger, or weaker, for less, or more, developed areas.

Our analysis reveals that those places that were initially more developed than other areas were relatively less affected by the rise of Boko Haram. As seen in Cols. (1)–(2) of Table 4.5, places that were relatively less developed are the places where the effect was most negative, with the overall effect about -0.14 (***). The overall effect in the third row corresponds to the combined effect of the effect of the BH 200 km x Post-09 dummy and its interaction with the chosen pre-2009 characteristic. When we examine the effect for places that were initially more developed (Cols. (3)–(4)), then we find that the interaction is strongly positive, enough to make the observed negative effect of BH—about -14 percent—

323 The stronger effects in Chad and Niger might be explained by the heterogeneous effects shown below or the fact that Chad's and Niger's regions close to Boko Haram historically disproportionately relied on their trade links with Northeastern Nigeria. In contrast, Cameroon's North was also trading with Southern Nigeria via Southern Cameroon (see Map 4.1). In particular, Niger's Southeast is poorly connected to the more developed Western areas of Niger and its Northeast correspond to the Sahara, hence its Southeastern areas' over-reliance on Northeastern Nigeria.

disappear (Col. (3)) or even turn positive (Col. (4); 0.11**).

Overall, while we found stronger negative effects for the more urban intensive sample than for the more rural extensive sample, within the intensive sample we actually find stronger negative effects for less developed areas (which may for example include small towns). If anything, the most developed areas relatively gained from (or lost relatively less) from the presence of BH. The relative gain in the most developed areas suggests that their sectors were more resilient to the BH shock, for example because they trade more with other places within their respective country, with other regions of Nigeria, or with neighboring countries. Likewise, these places may have attracted more economic outmigrants coming from negatively impacted areas.

To improve our understanding of the factors of resilience in the face of an economic shock brought about by foreign conflict, we next study heterogeneous effects related to trade diversification, agricultural development, infrastructure, human capital, and institutions.

4.6.2 Factors of Resilience to Foreign Conflict Shocks

We now examine the heterogeneous effects of other categories of initial (pre-2009) conditions. However, due to lack of data, we sometimes use post-2009 cell data. Next, in order to capture an interacted effect that is *different* from the interacted effect with initial development (or "explain" some of the interacted effect with initial development), we simultaneously control for the interaction of the BH 200 km x Post-09 dummy and the dummy equal to one if the cell's night light intensity is above the 75th percentile value in 2008. When doing so, we found that the average *residual* decline due to Boko Haram was 14 percent (see Col. (3) of Table 4.5). Finally, we study the interacted effect of each characteristic one at a time, mostly due to power issues.

Note that using the 10th and 90th percentile values captures a more local, possibly stronger, effect, that could be better identified as a result. At the same time, if the studied characteristic has an effect above the 10th percentile value of distance or below the 90th percentile value of distance, the effect may be mis-estimated because places above the 10th percentile or places below the 90th percentile are also directly affected by the characteristic.

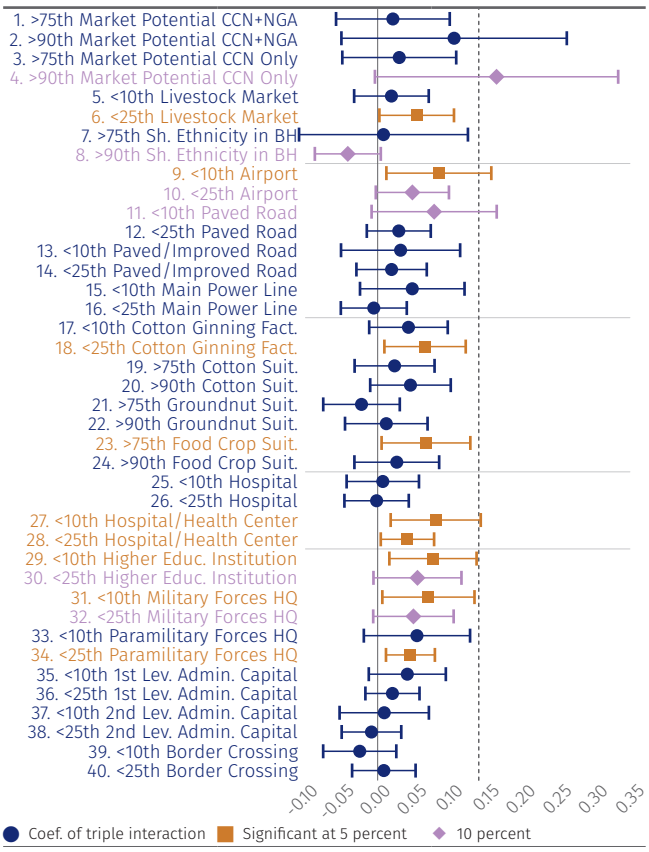
Table 4.5: Baseline Heterogeneous Effects of Boko Haram

Dep. Var.:	***Log (Mean Night Light Intensity + 1) in Year t***			
Interaction:	***Interaction of BH 200km * Post-09 with Dummy if Night Light Intensity in 2008 is ...***			
Percentile:	***Below 10th (1)***	***Below 25th (2)***	***Above 75th (3)***	***Above 90th (4)***
BH 200 km * Post-09	-0.001	-0.001	-0.135***	-0.110***
	[0.030]	[0.030]	[0.026]	[0.026]
Interaction	-0.135***	-0.135***	0.166***	0.216***
	[0.026]	[0.026]	[0.026]	[0.039]
Overall Effect	-0.14***	-0.14***	0.03	0.11**
	[0.03]	[0.03]	[0.03]	[0.04]
Cell FE, Cntry-Yr FE	Y	Y	Y	Y
Yr FE*Controls	Y	Y	Y	Y
Observations	21,644	21,644	21,644	21,644

Notes: The dummy used for the interaction withBH200km * Post-09 is constructed using the 10th, 25th, 75th and 90th percentile values of night light intensity in the cell's country in 2008. SEs clustered at the 3rd-level admin. unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

In that case, using the 25th or 75th percentile could help better estimate the effect. With the 25th or 75th percentile, more cells are included in the "relatively more treated" group, which may also improve precision. There is thus a trade-off. As a result, we report the effects for the 10th and 25th percentiles as well as the 75th and 90th percentiles. Figure 4.4 shows the interacted effects and their confidence intervals. Two vertical lines are added, one at 0 and one at 0.14. Indeed, a resilience effect of 0.14 is needed to offset the average residual decline due to Boko Haram (14 percent).[324]

Figure 4.4: Heterogeneous Resilience Effects Depending on Initial Local Conditions



Notes: The figure shows the interacted effect of the 200 km BH*Post-2009 dummy with the variable shown at left. Each row represents a separate regression. The 2nd vertical line is for x = 0.14 because 14 percent is the average residual decline due to Boko Haram (= the independent effect of the 200 km BH dummy). * p<0.10, ** p<0.05, *** p<0.01.

Trade Diversification. We first present our findings on heterogeneity based on market potential (MP). For each cell i and other cells j, MP of cell i is the weighted sum of the sum of night lights of other cells j, using as weights the driving time (in hours) circa 2008 between cell i and cell j to the power α. To begin, we assign to a cell the maximum speed between the speed(s) based on road categories applied in Jedwab and Storeygard (2020) and the speed of travel across off-road cells from a hiking function (Tobler, 1993) that incorporates slopes from Verdin et al. (2007). Then, we use the least-cost path algorithm to calculate the minimum travel time between each cell and each other cell.[325] Next, we assume $\alpha = 3$ in our baseline specification.[326] Finally, when crossing borders, we impose that drivers have to go through border crossings (whose locations we know for the year 2008). The cost to cross the border is then assumed to be 4 hours.

MP can first be defined using the cells of CCN and Nigeria but excluding the BH area itself since we aim to capture how the cell can trade with other areas than the BH area. As seen in rows 1–2 of Figure 4.4, we find a positive (but not significant) resilience effect if the cell is in the top 10th percentile in market potential in 2008 (no effect is observed for the top 25th percentile). The point estimate is relatively high, at 0.11, enough to almost offset the negative independent effect of the BH shock. Standard errors are high, with the 95 percent confidence interval values ranging from -0.05 to 0.26. We thus observe heterogeneous effects of the heterogeneous effect itself.

Nigeria's economy dramatically suffered as a result of Boko Haram and a cleaner test of the trade diversification hypothesis could be to define MP using only the cells of CCN, thus excluding Nigeria (rows 3–4). The effect with the 10th percentile value is now even

324 In the 40 specifications described below, the effect of BH 200 km x Post-09 is almost always equal to 0.14.

325 The road data come from Jedwab and Storeygard (2020). The data include information on the surface of each road in 2008, i.e. whether the road is a highway, a paved road, an improved (gravel or laterite) road, or a dirt road.

326 Results are generally not sensitive to the alpha used (not shown). A high α implies a high trade cost of distance, making cells farther away from cell i matter less. α is not known in our context. Jedwab and Storeygard (2020) use 3.8 but they study the effect of market potential for the whole continent, thus focusing on long-distance trade.

stronger (and significant). The point estimate—0.16—is enough to fully offset the Boko Haram shock and the 95 percent confidence interval values now range from 0.00 to 0.33. Therefore, some locations among the most connected locations might have even (relatively) gained with the BH shock.

While such locations perhaps trade more—which means that they could have been affected *relatively more* by the income shocks experienced in the BH areas—the positive effects may indicate that their economy is more diversified (i.e. they trade more in general, not just with Northeastern Nigeria). As a result, they may be *on net* less susceptible to foreign conflict shocks. More generally, taking the simple average across rows 3 and 4, we obtain +10 percent.

Next, we use the location of major livestock markets as a proxy for general markets. In the region, markets are used for agricultural products, cattle that is eventually exported to urban markets in Southern Nigeria or Southern Cameroon, and manufactured products bought with income from the sale of agricultural products and cattle. Given the lower demand from Nigeria, we could expect a negative interacted effect for the cells closest to the markets. At the same time, as livestock markets proxy for markets more generally, the negative effects could be (more than) compensated by positive effects for locations trading more in general. In addition, cattle can travel to Nigeria through other routes not impacted by the "closure" of the BH region.[327] We find positive effects of livestock markets (rows 5–6 of Figure 4.4). However, the effect is weaker for the 10th percentile value than for the 25th percentile value, possibly due to a more negative impact for locations specialized in cattle export. The positive and significant effect for the 25th percentile (+5 percent) may then capture a more general resilience effect for trade-oriented regions.

Rohner et al. (2013b) discuss how a lack of inter-ethnic trust hampers trade. Therefore, ethnically connected areas should trade more. Amarasinghe et al. (2020) then find that ethnic connectivity, among other factors, is particularly important for the diffusion of economic spillovers. We use the Murdock (1959) map to obtain for each cell the main ethnic group in terms of area in the cell. For each cell/group, we then obtain the share of the group's total homeland area that is within the BH area. By interacting this share with the BH 200 km x Post-09 dummy, this allows us to test if cells that were historically more "connected" to other cells in the BH area are more directly affected, likely because of stronger trade links with the BH area (via ethnicity-based trade networks). More precisely, we use dummies if the share is above the 75th or 90th percentile value in the country. As seen in row 8 of Figure 4.4, we find a negative significant effect of about -4 percent for the most connected cells (i.e., when using the 90th percentile). Thus, ethnic connectivity plausibly helped the diffusion of the economic shock caused by Boko Haram.

Infrastructure. We now investigate how infrastructure factors related to trade or not may have mattered for the diffusion of the economic shock as well as local economic resilience. We examine how proximity to airports mediates the impact of Boko Haram. We calculate the distance of each locality to all airports in the same country.[328] We find a positive and significant effect for the 10th and 25th percentiles (rows 9–10; +7 percent on average) but the effect is, as expected, higher for the 10th percentile. It could be that cities close to airports have specific sectors that are more resilient to land-based economic shocks (i.e. overland trade with Northeastern Nigeria).

Amarasinghe et al. (2020) show that road connectivity, along with ethnic connectivity, is a critical factor in the diffusion of economic spillovers. We use the road network database of Jedwab and Storeygard (2020)

327 The location of 81 livestock markets in Chad and 10 livestock markets in Cameroon (c. 2004–2005) is obtained from République du Tchad (2010). The location of 66 livestock markets in Niger (in the 2010s) is obtained from USGS FEWS.NET (2017). There are fewer markets in Cameroon as most of the cattle is produced in Chad or Niger.

328 The locations of airports (circa 2003) come from U. S. Geological Survey (2003).

to obtain for each cell and the year 2008 the minimal distance to a paved road (incl. highways), the minimal distance to a paved or improved road, and the minimal Euclidean distance to *all* roads (i.e., paved, improved, and dirt roads). We then create dummies based on whether the cell's distance to a paved road, a paved/improved road or any road is below the 10th or 25th percentile value in the country. As seen in rows 11–14, we find stronger effects for paved roads (+5 percent) than for other roads. The only significant effect is for the *most connected* cells, i.e. cells whose distance to a paved road is below the 10th percentile value in the country (+8 percent).

Other types of infrastructure that are not related to trade but possibly important include access to electricity and mobile networks. A reliable access to electricity is particularly important in countries where power failures are frequent. We thus investigate heterogeneity with respect to proximity to a major electricity transmission line, assuming that such locations are more protected against regional power outages. In rows 15–16 of Figure 4.4, we interact the BH 200 km x Post-09 dummy with a dummy if the cell's distance to a power line (c. 2008) is below the 10th or 25th percentile value in the country. We find a positive but not significant effect of +5 percent for the 10th percentile and no effect for the 25th percentile. The average effect is +2 percent.[329]

Next, we examine heterogeneity with respect to GSM coverage. More precisely, for each cell we obtain the area share that is covered by 2G mobile phone coverage c. 2009.[330] We then create dummies if coverage is above the 75th or 90th percentile value in the country. However, we do not find any effect (not shown, but available upon request). Therefore, infrastructure factors not related to trade do not appear as important as the ones related to trade in our context.

Agricultural Development. We turn to heterogeneity with regard to agricultural development. Two main cash crops are grown in the area, cotton and groundnut. With the shock, the demand from Nigeria likely decreased. At the same time, the supply of cotton and groundnut from Nigeria was also reduced, which may have increased prices for local producers. The effect of the shock on producing areas is thus ambiguous. In addition, if cash crop production is "fixed" in space, because of land suitability being an unsubstitutable factor of production or because of past sunk investments in transformation factories, then these locations remain valuable even in times of crisis. In that case, we might expect these areas to be affected relatively less.

We estimate mean cotton and groundnut production within 50 km from the cell's centroid. We then create dummies based on whether cotton suitability is higher than the 75th or 90th percentile value in the country.[331] Next, for cotton ginning factories, we use proximity to a factory, and thus create dummies if the cell's distance to a factory is below the 25th or 10th percentile value in the country. Finally, note that there was no formal groundnut oil extraction plant in the area during the period. Groundnut oil was instead extracted artisanally by local producers.[332]

As can be seen in Figure 4.4, we see positive interacted effects for cotton (rows 17–20; average affect of +4 percent), which are only significant in two out of the four cases. No effect is observed for groundnut (rows 21–22), possibly because it is considered a less profitable cash crop in the area.

329 Data is obtained from the Africa Infrastructure Country Diagnostic (AICD) database of the World Bank.

330 The source of the data on 2G mobile phone geographic coverage is the Global System for Mobile Communications (GSMA) c. 2009, who summarizes submissions of mobile operators data that provide representation of network coverage with roaming detail based on strong and variable signal strength.

331 The distance threshold of 50 km is arbitrary. Results hold with 100 km (not shown, but available upon request).

332 Cotton and groundnut suitability-based measures of production c. 2010 are from SPAM 2010 (IFPRI, 2019). According to their website: "SPAM relies on a collection of relevant spatially explicit input data, including crop production statistics, cropland data, biophysical crop 'suitability' assessments, population density, as well as any prior knowledge about the spatial distribution of specific crops or crop systems." The locations of cotton ginning factories are digitized from a map on *Cotton Zones, Ginning Factories and Exports of West Africa* in OECD (2006).

The interacted effect with overall food crop suitability then merits particular attention. Access to food crops is important because, in time of (urban) crisis, urban areas surrounded by land that is relatively more suitable for food production may be more resilient to the shock. People are more likely to stay in these locations to weather an economic shock. We interact the BH 200 km x Post-09 dummy with dummies based on food crop suitability (averaged across 12 major food crops in Sub-Saharan Africa).[333] We see positive interacted effects (rows 23–24; average effect of +5 percent, close to what we found for cotton). These are only significant for the 75th percentile.

Overall, the resilience effects appear weaker for agricultural development. However, if we focus on the cotton industry or food suitability, we find resilience effects that are about 5 percent on average.

Human Capital. Health infrastructure proxies for both human capital and government social expenditure as the health sector is mostly public in CCN. We construct measures of the distance to hospitals or health centers (2013–17) and create dummies based on whether it is below the 10th or 25th percentile value in the country.[334] We do not see any effect for hospitals (rows 25–26). When considering hospitals and health centers simultaneously, we then see positive significant effects (rows 27–28; average effect of +3 percent). The non-effects for hospitals suggests that these effects are not driven by health supply per se. Instead, locations with health centers might have higher levels of social services and offer higher levels of social protection in times of crisis.

We then examine heterogeneity with respect to higher education institutions (c. 2020), which are for the most part public universities in CCN. For each cell we obtain the Euclidean distance to a higher education institution and create dummies based on the 10th and 25th percentile values in the country.[335] As seen in rows 29–30, we find significant positive effects for both percentile values. The effects are on average twice higher than the effects found for health (+6 percent vs. +3 percent).

Government Expenditure. We examine more broadly if the effect of Boko Haram depends on government expenditure. Indeed, locations supported by the presence of government services may be more resilient due to the fact a larger share of their economy does not depend on local economic conditions but government budget allocations most often made at the national level. In addition, the presence of government services may also positively, or negatively, impact the ability of local economies to bounce back in the face of a massive economic shock.

We first examine heterogeneity with respect to major military and paramilitary headquarters (c. 2020 as information is not available for earlier years). For each cell we obtain the minimal Euclidean distance to a major military headquarter or a major paramilitary headquarter and create dummies based on the 10th and 25th percentile values in the country.[336] As seen in rows 31–34, the interaction effects are strong and significant in three out of the four cases (average of about +5 percent). The effect is larger for military headquarters than for paramilitary headquarters.

We then study if the effect of Boko Haram depends on proximity to "regional" capitals (for 1st level administrative units) or "district" capitals (2nd-level

333 FAO (2013) provides for the period 1981–2010 a measure of food crop suitability that is based on both soils and the climate and the following 12 crops: manioc (cassava), maize, rice paddy (Japonica), rice paddy (Indica), common wheat, sorghum (low alt.), common millet, potato, potato yam, sugar beet, cowpea and common bean.

334 We rely on Maina et al. (2019). Cameroon (2014–17), Chad (2013–16) and Niger (2013–17) have 183 (2,836), 41 (824) and 78 (1,151) hospitals (health centers), respectively. Data does not exist for the pre-2019 period.

335 The location of higher education institutions comes from Wikipedia, reports, and newspaper articles. Cameroon, Chad and Niger have 31, 21 and 11 such institutions, respectively. Data does not exist for the pre-2019 period.

336 Cameroon, Chad and Niger have 5 (15), 8 (23) and 10 (23) military (paramilitary) headquarters, respectively.

administrative units).[337] For each cell we obtain the Euclidean distance to a regional capital or a district capital and create dummies based on the 10th and 25th percentile values in the country. The effects are not significant (rows 35–38; +2 percent on average). The effect is larger for regional capitals than for district ones.

More broadly, one can see that the interacted effect is higher for military headquarters (about +6 percent) than for paramilitary headquarters (+5 percent), regional capitals (+3 percent) or district capitals (0 percent).[338] Thus, security might have been a more important concern than government employment. Given that Boko Haram had not entered CCN then, one interpretation could be that firms reduced investments as a result of increased uncertainty in the region, especially in potentially more unsafe areas located farther away from military and paramilitary headquarters.

Finally, we examine heterogeneity with respect to border crossings/posts. A negative effect could be expected in such areas due to reduced trade. However, such areas likely received more public investments and saw an increase in military and police presence. For each cell we compute the minimal Euclidean distance to a border crossing circa 2008 and then create dummies based on the 10th and 25th percentile values in the country.[339] As seen in rows 3–40, we find a negative, but insignificant, effect for the 10th percentile and no effect for the 25th percentile. As such, any negative effect due to reduced trade must have been offset by government expenditure.

To summarize, factors of resilience in the face of an economic shock brought about by foreign conflict include trade diversification and infrastructure related to trade (resilience effect of about +5–10 percent), agricultural development (+5 percent), human capital (+3–6 percent), and government expenditure (especially when related to security for which the resilience effect is about +5/+6 percent). We do not find significant effects for access to electricity or mobile networks, technologies that might only produce resilience if more resilient sectors are already present in the local economy.

While our results could have straightforward policy implications, one important caveat is that we only measure population, not real wages or welfare more generally. Some "better endowed" locations may have experienced a slower relative decline in their population possibly because they were also attracting economic refugees from equally affected neighboring locations. Our analysis only captures *relative* population growth patterns and suggests that initially (pre-shock) better endowed locations, by being more resilient, grow faster than less well endowed locations. As such, economic shocks due to foreign conflict may accentuate spatial inequality.

In addition, mostly due to power issues, we estimate each interacted effect one by one rather than simultaneously. Some of the heterogeneity variables are also correlated with each other and may as such capture similar dimensions.

337 For each country, we obtain a list of 1st-administrative level capitals—regional capitals (9 in Cameroon c. 2005, 22 in Chad c. 2020 and 7 in Niger c. 2014, respectively)—and a list of 2nd-administrative level capitals—departments capitals (48, 68 and 57, respectively). Sources used include the Humanitarian Data Exchange. While for Chad and Niger we use capitals defined post-2009, the total number of capitals barely changed there in the 2010s.

338 The coefficient of correlation between the 10th percentile dummies for these four types of government expenditure is between 0.16 and 0.65 (mean = 0.43). The dummies thus do not necessarily capture the same locations.

339 The locations of border crossings are obtained from Jedwab and Storeygard (2020).

4.7 Robustness and Other Considerations

Spatial autocorrelation. To account for spatial autocorrelation, we cluster standard errors at the 3rd level administrative unit (N = 343, 336, and 265 in Cameroon, Chad and Niger, respectively). We verify that the baseline negative effect of Col. (1) in Table 4.1 remains strongly significant when (Table A4.5): (i) clustering standard errors at the 2nd (36; 58; 53) or even 1st (8; 10; 23) administrative level; and (ii) using Conley standard errors using a distance cut-off of 100, 200 or even 300 km. However, given how computationally intensive computing Conley standard errors are when the number of spatial units is high, we first residualize the data, thus removing any variation due to the fixed effects and the controls. Using Conley standard errors is not feasible for regressions involving the full/extensive sample of cells, which we use for our analysis on the extensive margin of night lights, rural outcomes, and conflict. We also verify that these regressions and other regressions return similar results if we cluster standard errors at the 2nd or 1st administrative level (not shown, but available upon request). More generally, for the analysis on the extensive margin of night lights, greenness, land use and local conflict, we already find no effects. Thus, more conservative standard errors would not change our conclusions.

Other Definitions of the Treatment. For the sake of simplicity, proximity to BH is constructed using Euclidean distance to the BH area, which we define as the area of the states of Borno, Yobe and Adamawa that is between the Yobe river in the North (in Yobe) and the Benue river in the South (Adamawa). Table A4.6 shows that the results hold if we: (i) define the BH area as the state of Borno (where 60 percent of conflict events took place) or the full area of the Borno, Yobe and Adamawa; (ii) use a dummy for whether the cell is within 300 km from Maiduguri, Northeastern Nigeria's main city, which was particularly impacted by Boko Haram activities. We use 300 km instead of 200 km because Maiduguri is about 100 km from the border. The effects are stronger for Borno or Maiduguri, likely because these were more affected; (iii) use a dummy for whether the cell is within a 6.5 hours driving distance from the BH area. 6.5 hours corresponds to the 20th percentile in driving time to the BH area. We use the 20th percentile because 200 km corresponds to the 20th percentile in Euclidean distance to the BH area; and (iv) use the negative of the log distance to the BH area. The last two regressions are less comparable to our baseline regression. The coefficients, while different, remain strongly negative.

4.8 Conclusion

What are the spillover effects of foreign terrorism and conflict on regional economies? Adopting a difference-in-difference framework leveraging the unexpected rise of the Boko Haram insurgency in Northeastern Nigeria in 2009, we studied its effects in neighboring areas in Cameroon, Chad and Niger. We found strong negative effects on regional economic activities—proxied by reductions in nighttime lights—particularly amongst areas within 200 km from the Boko Haram area. Our findings suggested that this negative impact was concentrated in urban areas and was particularly pronounced among those areas that were initially less developed and connected, which highlights the role of trade diversification and infrastructure in mitigating the effects of economic shocks brought about by foreign conflict. We also found that the rise of Boko Haram resulted in more agricultural burning—an agricultural practice that is profitable in the short-term but typically leads to long-term environmental and economic losses.

Overall, these findings attest to both the short-term and long-term negative impacts of foreign conflicts on regional economies. More generally, we believe our findings might have important policy implications. First, conflicts have spillover effects that significantly impact regional economies as a whole, not only in the short run but also in the long run as well. For example, foreign conflicts push individuals in the urban sector to seek opportunities in the rural sector and engage in agricultural practices—namely, agricultural burning—that potentially jeopardizes long-run economic gains. Peace interventions can have positive effects "beyond" the country or countries in which they take place. Second, certain types of mitigation measures are perhaps more effective than others at alleviating the negative spillover economic effects of foreign conflict. In our context, initially more developed, connected, infrastructure-endowed, and government-protected areas were better able to "weather" the impact of the shock.

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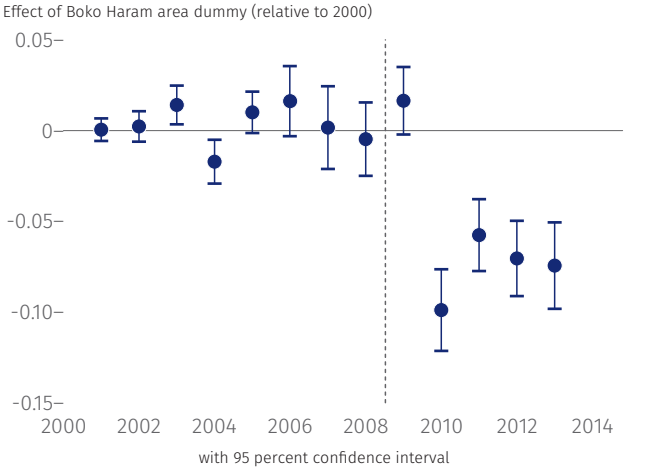
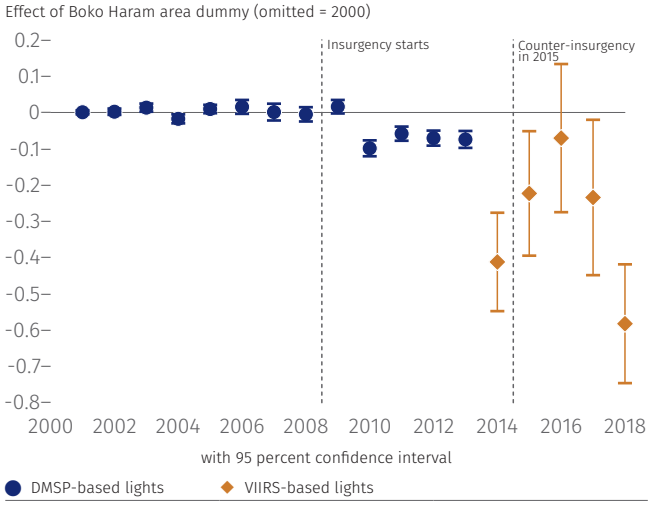
Appendix

Figure A4.1: Boko Haram Area Effect in Nigeria, 2000–2013



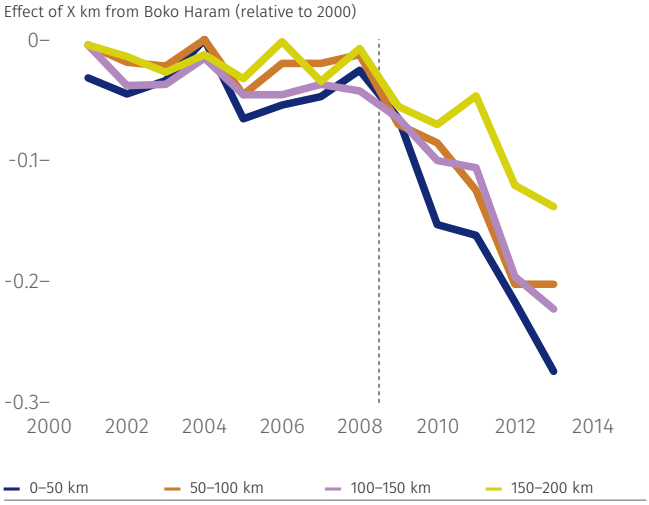
Notes: The figure shows for Nigeria the yearly effect (relative to the year 2000) of a dummy equal to one if the cell is within the Boko Haram area (the area of Borno, Yobe and Adamawa that is between the Yobe river in the North (in Yobe) and the Benue river in the South (Adamawa)). More precisely, we use data for 7,761 0.1×0.1 degree grid cells (≈ 11x11km at the equator) in Nigeria for the years 2000–2013 (hence N = 108,654). The dependent variable is the log of mean light intensity (sum of lights divided by area + 1) in cell *c* in year *t*. We include cell c fixed effects, year t fixed effects, and interact the *Boko Haram area* dummy *c* (equal to one if the cell is within the Boko Haram area or if its centroid is within 10 km from the area's border) with a dummy for each year *t* in 2001–2013. Standard errors are clustered at the Local Government Area (LGA; N = 721). With 7,761 cells, there are 11 cells per LGA.

Figure A4.2: Boko Haram Area Effect in Nigeria, 2000–2018



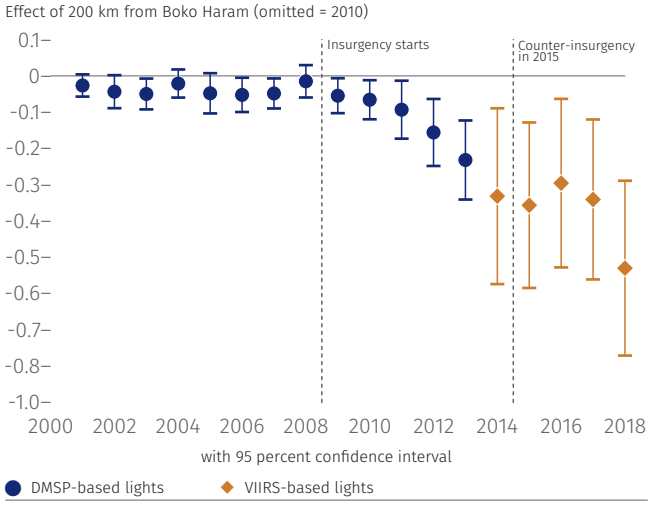
Notes: We use the same panel-DiD model as for Fig. A4.1 except that we now consider the full period 2000–2018. For this analysis we rely on the harmonized NTL data (1992–2018) from Li et al. (2020) who combine night light data from OLS-DMSP (used until 2013) and SNPP-VIIRS (use for the period 2014–2018). Note that the high standard errors for the VIIRS observations in 2014–2018 likely reflect the fact that the assumptions made by Li et al. (2020) to recreate harmonized NTL for the whole period 2000–2018 also introduced a significant amount of noise.

Figure A4.3: Boko Haram Area Effect in Cameroon, Chad and Tchad, 50 Km Bins, 2000–2013



Notes: For 1,546 cells in Cameroon, Chad and Niger, we use the same panel-DiD model as eq. (1) except that we now separate the 0–200 km Boko Haram Area Dummy into four dummies for whether the cell is within 0–50 km, 50–100 km, 100–150 km or 150–200 km from the Boko Haram area (1,546 cells x 14 years = 21,644 obs.). To avoid the figure being too cluttered, we do not report confidence intervals. See text for details on the specification.

Figure A4.4: Boko Haram Area Effect in Cameroon, Chad and Niger, 2000–2018



Notes: For 1,320 cells in Cameroon, Chad and Niger (CCN), we use the same panel-DiD model as eq. (1) except that we now consider the full period 2000–2018 (1,320 cells x 19 years = 25,080 obs.). We start with the sample of 1,546 cells but exclude cells having ever experienced a Boko Haram event during the period of study as well as cells within 50 km from these cells. We also control for the log of the Euclidean distance to any CCN cell with a Boko Haram event in the same year *t*. For this analysis we rely on the harmonized NTL data (1992–2018) from Li et al. (2020) who combine night light data from OLS-DMSP (used until 2013) and SNPP-VIIRS (use for the period 2014–2018). Note that the high standard errors for the VIIRS observations in 2014–2018 likely reflect the fact that the assumptions made by Li et al. (2020) to recreate harmonized NTL for the whole period 2000–2018 also introduced a significant amount of noise.

Table A4.1: Effects of Boko Haram on Domestic Conflict, ACLED Database, 2000–2013

Conflict Measure:	***All Events***	***Combined (Including Fatalities)***	***Battles***	***Violence Against Civilians***	***Protests or Riots***	***Non-Violent Strategic Dev.***	***Explosions & Remote Violence***
Panel A. *Dep. Var.: Dummy if Non-Boko Haram Conflict Event in the Cell in Year t*							
BH 200Km* Post-09	0.0002	–	-0.0003	0.0004	0.0002	0.0000	0.0002
	[0.0004]	–	[0.0003]	[0.0003]	[0.0003]	[0.0001]	[0.0002]
Panel B. *Dep. Var.: Number of Non-Boko Haram Conflict Events in the Cell in Year t*							
BH 200Km* Post-09	0.0024	0.0212	0.0016	0.0005	0.0001	-0.0001	0.0002
	[0.0022]	[0.0129]	[0.0018]	[0.0004]	[0.0004]	[0.0002]	[0.0002]
Cell FE, Cntry-Yr FE	Y	Y	Y	Y	Y	Y	Y
Yr FE*Controls	Y	Y	Y	Y	Y	Y	Y
Observations	356,874	356,874	356,874	356,874	356,874	356,874	356,874

Notes: SEs clustered at the 3rd-level admin. unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A4.2: Effects of Boko Haram on Domestic Conflict, UCD Database, 2000–2013

Conflict Measure:	***All Events***	***Combined (Incl. Fatalities)***	***Type of Organized Violence***		
			State	***Non-State***	***One-Sided***
Panel A. *Dummy if Non-Boko Haram Conflict Event in the Cell in Year t*					
BH 200Km * Post-09	0.0003	–	0.0000	0.0000	0.0003**
	[0.0002]	–	[0.0001]	[0.0000]	[0.0002]
Panel B. *Dep. Var.: Number of Non-Boko Haram Conflict Events in the Cell in Year t*					
BH 200Km * Post-09	0.0009	0.0299	0.0004	0.0000	0.0005*
	[0.0007]	[0.0236]	[0.0004]	[0.0000]	[0.0003]
Cell FE, Cntry-Yr FE	Y	Y	Y	Y	Y
Yr FE*Controls	Y	Y	Y	Y	Y
Observations	356,874	356,874	356,874	356,874	356,874

Notes: SEs clustered at the 3rd-level admin. unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A4.3: Effects of Boko Haram on Domestic Conflict, SCAD Database, 2000–2013

Conflict Measure:	***All Events***	***Combined (Incl. Fatalities)***	***Type of Social Conflict***			
			Demonstration	***Riot***	***Strike***	***Violence***
Panel A. *Dummy if Non-Boko Haram Conflict Event in the Cell in Year t*						
BH 200Km * Post-09	0.0005	–	0.0003	0.0003	0.0002	-0.0001
	[0.0005]	–	[0.0003]	[0.0002]	[0.0002]	[0.0003]
Panel B. *Dep. Var.: Number of Non-Boko Haram Conflict Events in the Cell in Year t*						
BH 200Km * Post-09	0.0010	0.0024	0.0007	0.0003	0.0001	-0.0001
	[0.0007]	[0.0020]	[0.0004]	[0.0002]	[0.0003]	[0.0003]
Cell FE, Cntry-Yr FE	Y	Y	Y	Y	Y	Y
Yr FE*Controls	Y	Y	Y	Y	Y	Y
Observations	356,874	356,874	356,874	356,874	356,874	356,874

Notes: SEs clustered at the 3rd-level admin. unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A4.4: Effects on Domestic Conflict, 2000–2013, Excluding Military Headquarters Cells

Conflict Database:	***ACLED (Armed Conflict)***			***Uppsala (Armed Conflict)***			***SCAD (Social Conflict)***		
Sample:	***All (1)***	***Intensive (2)***	***Extensive (3)***	***All (4)***	***Intensive (5)***	***Extensive (6)***	***All (7)***	***Intensive (8)***	***Extensive (9)***
Panel A. *Dep. Var.: Dummy if Non-Boko Haram Conflict Event in the Cell in Year t*									
BH 200Km * Post-09	-0.0005	-0.0056*	-0.0004	0.0001	0.0011	0.0001	-0.0004	-0.0052	0.0001
	[0.0004]	[0.0031]	[0.0003]	[0.0001]	[0.0020]	[0.0001]	[0.0004]	[0.0032]	[0.0002]
Panel B. *Dep. Var.: Number of Non-Boko Haram Conflict Events in the Cell in Year t*									
BH 200Km * Post-09	-0.0016*	-0.0337**	-0.0004	0.0000	0.0014	0.0000	-0.0004	-0.0063*	0.0002
	[0.0009]	[0.0162]	[0.0006]	[0.0002]	[0.0034]	[0.0001]	[0.0004]	[0.0036]	[0.0002]
Cell FE, Cntry-Yr FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Yr FE*Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	302,344	12,796	289,548	302,344	12,796	289,548	302,344	12,796	289,548

Notes: SEs clustered at the 3rd-level admin. unit. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A4.5: Post-2009 Effect of Proximity to the Boko Haram Area, Lights, Alternative SEs

Dependent Variable:	***Log (Mean Night Light Intensity + 1) in Year t***					
Standard errors:	***SEs Clustered using Admin. units***			***Conley SEs - Distance Cut-Off =***		
	Level 3 (1)	***Level 2 (2)***	***Level 1 (3)***	***50 km (4)***	***100 km (5)***	***200 km (6)***
BH 200Km * Post-09	-0.097***	-0.097***	-0.097**	-0.097***	-0.097***	-0.097***
	[0.027]	[0.031]	[0.038]	[0.029]	[0.034]	[0.036]
Cell FE, Cntry-Year FE	Y	Y	Y	Y	Y	Y
Year FE*Controls	Y	Y	Y	Y	Y	Y

Notes: Obs.: 21,644. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A4.6: Post-2009 Effect of Proximity to Boko Haram, Alternative Measures of the Shock

Dependent Variable:	***Log (Mean Night Light Intensity + 1) in Year t***					
Measure:	***Baseline (1)***	***Borno Only (2)***	***Borno + Yobe + Adamawa (3)***	***City of Maiduguri (4)***	***Driving Time (5)***	***Log Dist. to BH Area (6)***
BH 200 Km * Post-09	-0.097***	-0.123***	-0.057**			
	[0.027]	[0.038]	[0.026]			
Maiduguri 300Km * Post-09				-0.119***		
				[0.039]		
BH 6.5 Hrs * Post-09					-0.044**	
					[0.018]	
(-) Log Dist. BH * Post-09						-0.033***
						[0.012]
Cell FE, Cntry-Year FE	Y	Y	Y	Y	Y	Y
Year FE*Controls	Y	Y	Y	Y	Y	Y

Notes: Obs.: 21,644. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Technical Paper 4. Infrastructure and Structural Change in the Lake Chad Region

Mathilde Lebrand (World Bank)

5.1 Introduction

Infrastructure investments can support economic development through both capital accumulation and structural transformation.[340] Structural change, the movement of workers from lower to higher productivity employment, is seen as essential to growth in low-income countries. This paper investigates how investments in electricity, internet, transport infrastructure, and their interactions, affect economic development through productivity gains and structural change in countries around the Lake Chad. Roads provide access to markets, increasing both economic opportunities for local firms and competition from other locations. Electricity and internet allow for modern production technologies and complement roads by boosting firm productivity. While the literature has studied specific infrastructure expansions as potential drivers of development, little has been done on the associated structural change and how the combinations of such investments will matter.

This paper focuses on the impact of infrastructure on economic development for the countries around the Lake Chad area, an economically- and socially-integrated area in north-west Africa that has development potential, but which has been undermined by multiple and interrelated drivers of fragility, conflict, and violence. The Lake Chad region comprises a set of administrative areas across Cameroon, Chad, Niger, and Nigeria that surround Lake Chad, with an estimated 17 million to 19 million people, who are primarily involved in agriculture and fishing activities. The region has one of the largest concentrations of extreme poverty in Sub-Saharan Africa and the world and lags in human development outcomes and access to key public services. The paper analyzes the impact of infrastructure in Cameroon, Chad and Nigeria, from a national and regional perspective, and with a particular focus on the Lake Chad area.

All four countries, while being at different stages of development, face a similar challenge to generate more adequate-quality jobs through economic transformation. Employment in nonagricultural sectors is currently around 55 percent in Cameroon, 65 percent in Nigeria, and less than 30 percent in Niger and Chad (World Bank data, see Figure A5.1 in the appendix). The share of employment in agriculture in Cameroon and Nigeria has been declining since the 1990s, while it has stagnated at high levels for Niger and Chad. Overall, the pace of structural change has remained slower than expected in the region, hence the need to better understand the role of infrastructure as a driver of structural transformation.

Because the Lake Chad region is characterized by strong historical trade, ethnic, cultural, and political ties, which makes the areas within countries that comprise the region economically interdependent, we finally consider regional integration and cross-border linkages when assessing the impact of further infrastructure investments. The region and its vicinities host some key cities—such as Maiduguri in Nigeria, Maroua and Kousseri in Cameroon, N'Djamena in Chad, and Diffa in Niger—that could serve as a trade hub that could potentially drive the regional economy. However, connectivity across the borders (or between these cities within the national boundaries) is poor due to a lack of road infrastructure and volatile security situations that make trade or transportation of goods too costly. The paper complements the economic analysis of key infrastructure investments with additional border investments.

340 There are two approaches for explaining economic growth (McMillan et al., 2017). The first one assumes that the accumulation of skills, capital, and broad institutional capabilities are needed to generate sustained productivity growth. The second approach assumes a dual economy where long-run growth is driven by the flow of resources to the modern economic activities that operate at higher levels of productivity.

The paper is divided in two parts. The first part uses reduced-form analysis to quantify the impacts of past investments in electricity, internet, and road infrastructure on the sectoral structure of employment in Cameroon, Nigeria, and Chad. The second part uses a spatial general equilibrium model, based on Moneke (2020), to assess the aggregate and spatial impacts of planned infrastructure investments in the region. Reduced-form results capture the localized effects in the areas that have been affected, but do not capture the general-equilibrium effects and spillovers due to the network nature of infrastructure such as roads. The general-equilibrium model captures the spillover effects that a localized investment has on the rest of the country and all the countries in the Lake Chad region and generates welfare estimates for the entire region and all its subregions.

We first provide evidence on how past investments and their combinations mattered for structural transformation in countries around the Lake Chad, which includes Cameroon, Nigeria, Niger, and Chad. Facing endogenous infrastructure investments with respect to sectoral employment outcomes across time and space, we use several instrumental variables to overcome these endogeneity concerns. We then study the average and heterogenous effects to understand whether leading or lagging regions benefit differently from such investments. As the pace of structural change remains slow in the region, we provide counterfactual evidence to which extent a push for more regional integration through the expansion of transport and trade infrastructure would support economic development and structural transformation.

The objective of this work is to extend our understanding on the impact of infrastructure investments across several neighboring countries in Africa. The novelties of this work are to assess the interactions between different infrastructures and how it affects the sectoral structure of employment at the district level, and to assess the impacts of several planned transport investments and trade facilitation measures in neighboring countries that are at different stages of development. A companion paper undertakes similar work for countries in the Horn of Africa (Herrera Dappe and Lebrand, 2021).

Our paper is related to a number of different strands of research. First, our work contributes to research on the different impacts of infrastructure. Several papers have examined the impact of infrastructure investment on sectoral employment at the micro-level (Adukia et al., 2020; Asher and Novosad, 2018; Gertler et al., 2016). In the case of roads, lower transport costs empower women by opening labor market opportunities and increase their employment in the non-agricultural sector (Gertler et al., 2016). However most papers have considered the gains from energy, transport and digital investments in isolation or bundled in a unique infrastructure index. The aggregate impact of infrastructure has been measured through the elasticity of output with respect to a synthetic infrastructure index, which includes transport along with electricity and telecommunications (Calderon et al., 2015). More recently, Moneke (2020) shows that interactions of transport and electricity investments are complementary and gave rise to large effects on economic development in the context of Ethiopia. He finds starkly different patterns of big push infrastructure on sectoral employment compared to only road investments: roads alone cause services employment to increase at the expense of agriculture and, especially, manufacturing employment. In contrast, the interaction of roads and electrification causes a strong reversal in manufacturing employment. Our paper is similar but includes investments in digital infrastructure, and covers more countries.

Finally, our paper contributes to the long literature using quantitative spatial general equilibrium models to provide counterfactuals for infrastructure investments. We look at the general equilibrium effects of road and border investments via changes in trade costs that lead labor to reallocate across locations such as Allen and Arkolakis (2014) and Redding (2016). Bustos et al. (2016) and Fried and Lagakos (2020) study general equilibrium implications of electrification via its effect on productivity. Michaels et al. (2011) look at changes in sectoral employment as outcome of interest that captures the underlying infrastructure-induced effects. Several

papers provide policy counterfactuals for future road and border infrastructure improvements for the Belt and Road Initiative (Lall and Lebrand, 2020; Bird et al., 2020), in Bangladesh (Herrera Dappe and Lebrand, 2019), and between Bangladesh and India (Herrera Dappe et al., 2021).

The paper is structured as follows. Section 2 presents the data. Section 3 presents the empirical strategy and results. Section 4 develops a spatial general-equilibrium model to produce counterfactuals for more regional integration. Section 5 concludes.

5.2 Data

In this paper, we complement household survey data that have been geolocalized with new spatial infrastructure data in order to study links between access to infrastructure and structure of the local economies, and the complementarities between the different types of infrastructure.

5.2.1 Sources of data

Infrastructure. We start by collecting new information on road network expansions, access to the electricity network, and access to the internet fiber backbone. Table 5.1 summarizes the data sources and years of coverage.

First, we collect geospatial maps of road expansion using governmental sources but also previously-harmonized collections of road networks (Foster and Briceno-Garmendia, 2010; Jedwab and Storeygard, 2020). The quality of the network and associated features, and the frequency of updates vary across countries. For all three countries, we first rely on data from Foster and Briceno-Garmendia (2010) that cover all African roads networks around the year 2007 based on surveys and governments sources. We complement each network with data from recent government surveys for Cameroon and Chad, and from the work of Ali et al. (2015) for Nigeria. In the latest, geographic information system road network data are combined with road survey data from the Nigeria Federal Roads Maintenance Agency (FERMA) and the World Bank's Fadama project.[341] Panels of roads from the same source are rare. Related works include a similar paper applied to the Horn of Africa (Herrera Dappe and Lebrand, 2021) and Moneke (2020) whose focus on 'all-weather' (i.e. gravel, asphalt or bitumen surface) roads is closer to ours.

Second, we use two methods to map access to the electricity network, nighttime lights as a proxy for access to electricity and maps of the power transmission grids. Nighttime lights are available for most years and locations but convey imperfect information on electrification. Historical maps of electricity grids are more difficult to find and use in a consistent way. First, we use satellite images of annualized nighttime lights and population rasters to calculate the percentage of

Table 5.1: Summary of Infrastructure data

Infrastructure	*Country*	*Year*	*Source*
Roads	Nigeria	1991	Jedwab and Storeygard (2020)
	Nigeria	2009	Jedwab and Storeygard (2020)
		around 2013	Ali et al. (2015)
	Cameroon	2009	Foster and Briceno-Garmendia (2010)
		2018	Road authorities
	Chad	2009	Foster and Briceno-Garmendia (2010)
		2018	Road authorities
Electricity	All	vary across countries	Nighttime lights/Population raster
Electricity grid	All	around 2006	Foster and Briceno-Garmendia (2010)
	All	most recent	gridfinder.org and Arderne et al. (2020)
Internet	All	2009–2019	Africa Bandwidth Maps 2009–19

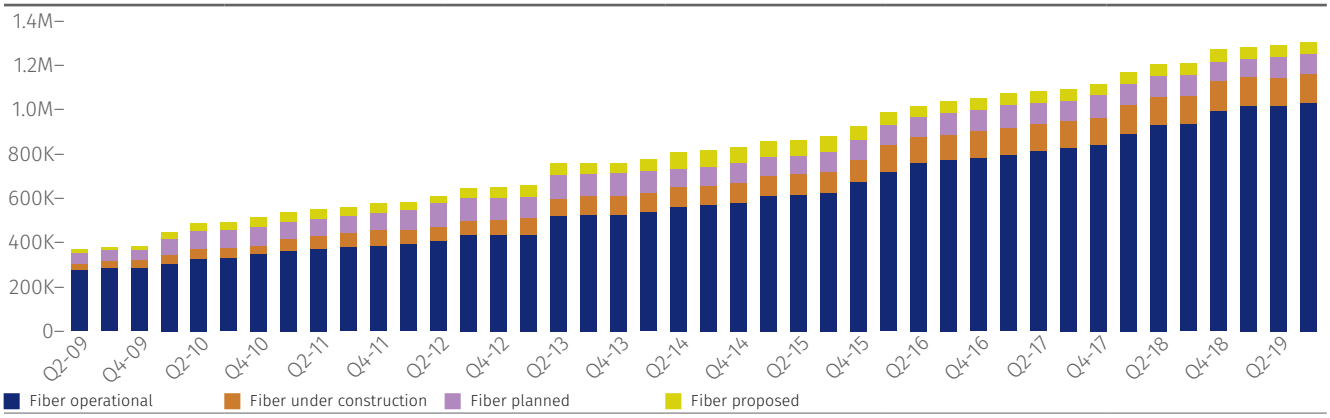
341 To "ground truth" and take advantage of first hand local knowledge, government offices across Nigeria were surveyed about the conditions of specific road segments near them.

electrified population, meaning population in settlements that produce some lights at night. We compare the results for two metrics: a dummy that is equal to one if at least 50 percent of the population has access to electricity as defined previously, and the percentage of electrified population per district. Sensitivity checks show that the choice of the threshold does not significantly change the results.[342] Such methods have been used before to estimate electricity access in remote areas and guide grid extension programs.[343] They assume that locations that emit lights at night are settlements that have electricity access, and that their electricity is most likely supplied from an electrical grid. It also assumes that small off-grid systems do not emit enough light to be captured by satellites, but larger isolated power networks certainly do. We cross-check the numbers that we get with country estimates of electrified population over years from the World Bank.[344] Figure A5.2 in the appendix shows the results for the percentage of electrified population for all countries.

We also collect information on transmission grids based on past efforts to harmonize data for infrastructure from primary sources and recent mapping strategies to infer the electricity grids based on satellite data. For past data, we use electricity grids from the Africa Infrastructure Country Diagnostic (AICD) which collected primary data covering network service infrastructures from 2001 to 2006 in 24 selected African countries. To complement these data, we rely from on a recent effort by the World Bank, Facebook and other institutions (KTH, ESMAP, WRI and the University of Massachusetts Amherst) to use remote sensing, machine learning and big data to map connected populations and the systems that support them. They create an algorithm for estimating the location of existing medium-voltage infrastructure based on nighttime lights and the location of roads assuming that medium voltage lines are more likely to follow (or be followed by) main roads.[345] Figure A5.21 in the appendix shows the grid for the Lake Chad using the 2009 grid from Foster and Briceno-Garmendia (2010) and using the most recent grid.

Internet infrastructure is proxied by access to the fiber broadband backbone network. We obtained data for all Africa for the period 2009–2020 with the exact location of fiber nodes along the backbone network from Africa Bandwidth Maps. We construct a proxy for access to the fiber backbone which is equal to one if there is a node of the backbone in the location of interest. Each node has a year attribute which allows us to build a panel for

Figure 5.1: Route-Kilometers of Terrestrial Transmission Network, Africa 2009–2019



Source: http://www.africabandwidthmaps.com/

342 There is a large concentration of data points around 0 and 100 percent, which explains that the choice of the threshold, being the mid-point of the average, does not have a strong impact on the analysis.

343 An example of mapping rural electrification based on nighttime lights can be found at http://india.nightlights.io/

344 The World Bank reports access to electricity (percent of population) for most countries for a long time period at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.

345 More details can be found on the blog https://blogs.worldbank.org/energy/using-night-lights-map-electricalgrid-infrastructure and in the paper Arderne et al. (2020).

access to the backbone. We assume that access before 2008 is null everywhere, which is supported by World Bank data on access to internet which reports that less than 4 percent of individuals in Sub-Saharan countries (including high-income countries) have access to internet in 2008. Figure 5.1 shows the growth of the network for the whole of Africa, and Figures A5.8, A5.12, A5.18 show the geographic evolution per country. However, internet access remains unequal across countries as some countries have a broad internet coverage while others are still lagging. We cross-check our numbers using the World Bank indicators reporting the percentage of individuals using the internet.[346]

Employment. We are interested in structural transformation, which we interpret in line with the literature (Herrendorf et al., 2014) as changes in sectoral employment. Following Moneke (2020), we require information on sectoral employment shares, which we derive from the Demographic & Health Survey (DHS). The DHS produces harmonized survey data with GPS coordinates available for most surveys and is available for several rounds per country. The DHS is a repeated cross-section of enumeration areas (EA), with approximately 20 to 30 households enumerated per EA. In total, five rounds in Nigeria [1990, 2003, 2008, 2013, 2018], four rounds in Cameroon [1991, 2004, 2011, 2018], and one round in Chad, summarized in Table 5.2. Unfortunately we are not able to cover Niger.

We use DHS data for which we have access to the occupation of the individuals as well as a proxy for their location. In order to construct the shares of employment per sector, we use respondents' answer to questions about their current occupation. We first compute the shares of non-working individuals, and then we group the working individuals into three sectors, agriculture, manufacturing and services. We aggregate individual responses to the enumeration area and then generate an unbalanced panel of districts that have at least one EA during a survey round. The DHS-provided GPS coordinates for EAs locations are not perfectly reliable due to the common random displacement applied to GPS coordinates for anonymity.[347] We aggregate EAs per geographic location.

Table 5.2: Survey data

Data	*Country*	*Year*	*Source*
Household surveys	Nigeria	1990, 2003, 2008, 2013, 2018	DHS
	Cameroon	1991, 2004, 2011, 2018	
	Chad	2014	

Table 5.3: Additional district-level data

Population	GHSL
Land	ESA Land Cover
Distance to the coast	GSHHG
Distance to the border	Aiddata database
Access to a city >50,000 inhabitants	The Malaria Atlas Project
Temperature	Land Processes Distributed Active Archive Center
Elevation	CGIAR-CSI

Usages of infrastructure. In addition of access to infrastructure, we consider how usages linked to roads, electricity and ICT infrastructure impact the structure of employment. We include variables from the DHS surveys that cover access to electricity as reported by the households, ownership of cars and motorcycles, ownership of land phone and mobile phone, and use of internet. We aggregate the answers at the subnational level of interest as percentage of individuals that have access to electricity, own a car, a motorcycle, a land phone, a mobile phone, or use internet. The analysis of usage complements the analysis of infrastructure investments. Not all variables are available for the whole period so we restrict our analysis to the period 2008–2018.

346 The World Bank reports access to internet (percent of population) for most countries for a long time period at https://data.worldbank.org/indicator/WeT.NET.USER.ZS. based on International Telecommunication Union, World Telecommunication/ICT Development Report and database.

347 DHS coordinates of rural (urban) EAs are randomly displaced within a 0–10km (0–5km) radius.

District characteristics. We use additional data to control for district heterogeneity as described in Table 5.3. First, we use population from satellite data from GHSL[348], land categories from ESA land cover[349], distance from the coast from GSHHG[350], distance to the border[351], access to a city larger than 50,000 inhabitants from the Malaria Atlas Project,[352] temperature from Land Processes Distributed Active Archive Center[353], and elevation from CGIAR-CSI[354].

5.2.2 Access to infrastructure

We compare access to infrastructure for paved roads, electricity, and internet broadband for Nigeria, Cameroon and Chad after 2000. Figures 5.2, 5.3, and 5.4 report summary statistics of the infrastructure variables used in the next sections at the country level, and Figure 5.5 focuses on the smaller area around the lake Chad.

Nigeria has the highest level of access to paved roads and electricity with more than 90 percent of the districts and population having access to a paved road in 2018. While access to paved roads has barely changed since 2000, access to electricity has increased significantly from 35 percent to 56 percent of districts having access to electricity between 2003 and 2018.[355] 23 percent of districts are connected to the fiber network as defined by the presence of a node from the fiber backbone.

In Cameroon, 60 percent of the communes and 80 percent of the population are connected to a paved road. The coverage falls when restricting access to fair or good paved roads. Access to electricity and internet covers a small number of communes but the most populated ones as the percentage of population is almost twice the percentage of communes. Between 2003 and 2018, the number of communes covered has more than double but the percentage of population covered has increased by only 7 percent percentage points from 41 percent. The additional communes that have received electricity coverage over the last two decades are much less populated.

Access to infrastructure in Chad is very limited compared to other countries. In 2014, only 2.6 percent of communes had access to a paved road, 3 percent to the internet broadband, and 6 percent to the electricity network. The covered communes are the most populated ones, as 20 percent of the population has access to electricity and 15 percent of the population has access to the internet broadband. Recent improvements of the paved road network since 2014 as shown in Figure A5.17 show that the percentage of communes and population having access to a paved road has largely increased.

The Lake Chad area, which includes The Extreme North region in Cameroon, the regions of Kanem, Lac, Hadjer-Lamis, and Chari-Baguirmi in Chad, and the regions of Borno, Yobe and Adamawa in Nigeria as depicted on Figure A5.20, is characterized by a limited access to infrastructure. Only 30 percent

348 GHSL: Population count from the Global Human Settlement Layer. Based on population data from Gridded Population of the World v4.10 polygons, distributed across cells using the Global Human Settlement Layer global layer. Source data provided in 9 arc-second (250m) grid cells.

349 ESA land cover: Defourny, P. (2017): ESA Land Cover Climate Change Initiative (Land Cover cci): Land Cover Maps, v2.0.7. Centre for Environmental Data Analysis, 7/2017.

350 Distance to coast (on land only), measured in meters. Derived using World Vector Shorelines. Wessel, P., and W. H. F. Smith, A Global Self-consistent, Hierarchical, High-resolution Shoreline Database, J. Geophys. Res., 101, B4, pp. 8741-8743, 1996.

351 Distance to country borders, measured in meters. Derived using GADM 2.8 ADM0 (Country) boundaries.

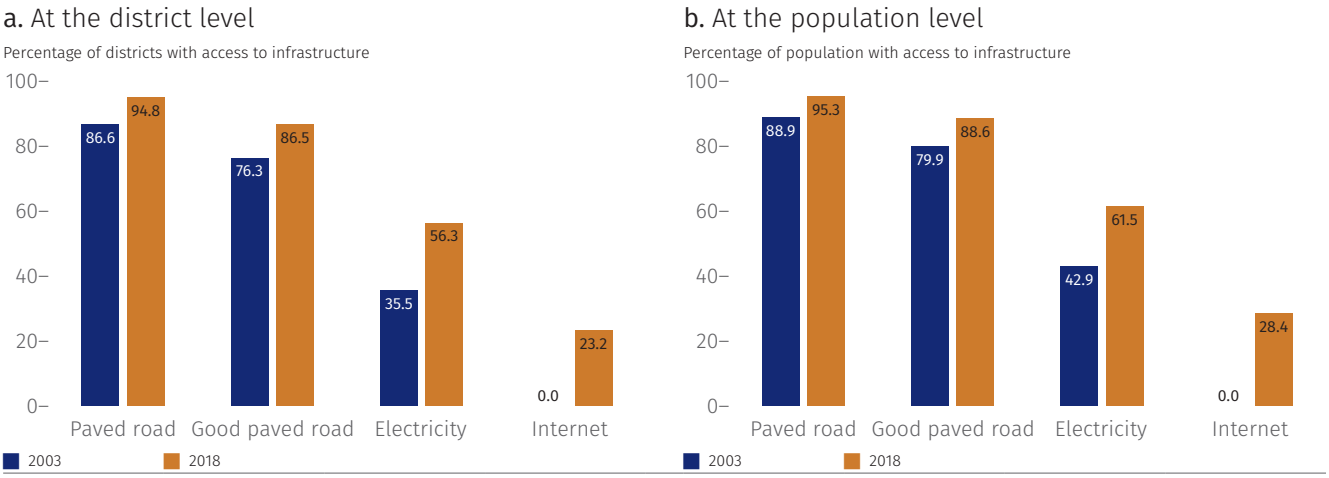
352 Incorporates data from Open Street Map (OSM) data and the Google roads database. D.J. Weiss, A. Nelson, H.S. Gibson, W. Temperley, S. Peedell, A. Lieber, M. Hancher, E. Poyart, S. Belchior, N. Fullman, B. Mappin, U. Dalrymple, J. Rozier, T.C.D. Lucas, R.E. Howes, L.S. Tusting, S.Y. Kang, E. Cameron, D. Bisanzio, K.E. Battle, S. Bhatt, and P.W. Gething. A global map of travel time to cities to assess inequalities in accessibility in 2015. (2018). Nature. doi:10.1038/nature25181.

353 Yearly daytime land surface temperature. Wan, Z., Hook, S., Hulley, G. (2015). MOD11C3 MODWeS/Terra Land Surface Temperature/Emissivity Monthly L3 Global 0.05Deg CMG V006 [Data set]. NASA EOSDWeS LP DAAC. doi: 10.5067/MODWeS/MOD11C3.006.

354 Global elevation (in meters) from Shuttle Radar Topography Mission (SRTM) dataset (v4.1) at 500m resolution. Jarvis A., H. We. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT), available from http://srtm.csi.cgiar.org.

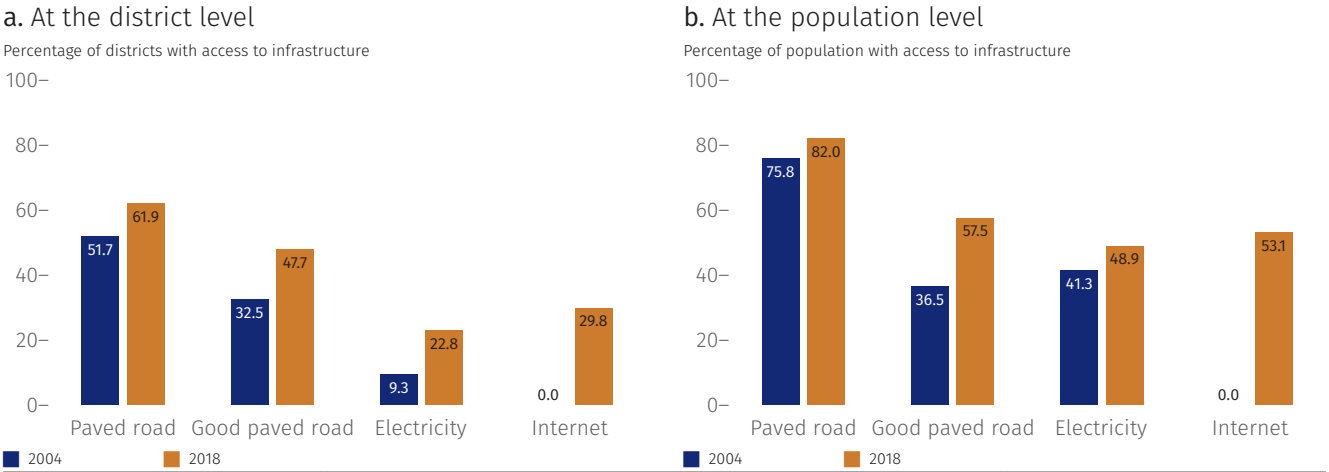
355 A district is classified as electrified when at least 50 percent of its population has access to electricity as monitored with nighttime lights.

Figure 5.2: Access to infrastructure in Nigeria



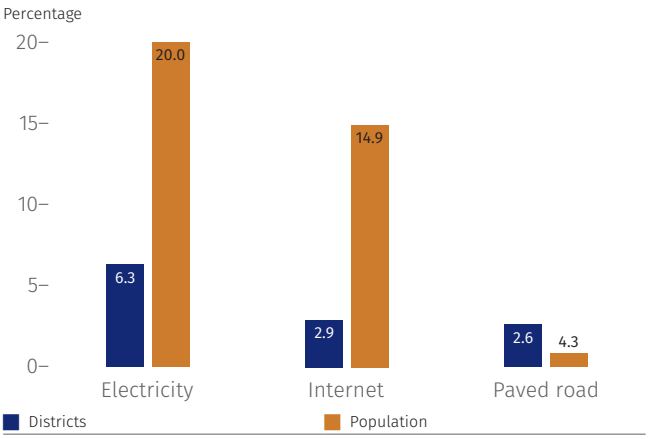
Note: Authors' calculations using data sources listed in previous section. Good paved roads include roads of fair or good condition. The left graph shows the percentage of districts (admin 2 for Nigeria), the right graph the percentage of population using the 2015 district population.

Figure 5.3: Access to infrastructure in Cameroon



Note: Authors' calculations using data sources listed in previous section. The left graph shows the percentage of districts (admin 3 for Cameroon), the right graph the percentage of population using the 2015 district population.

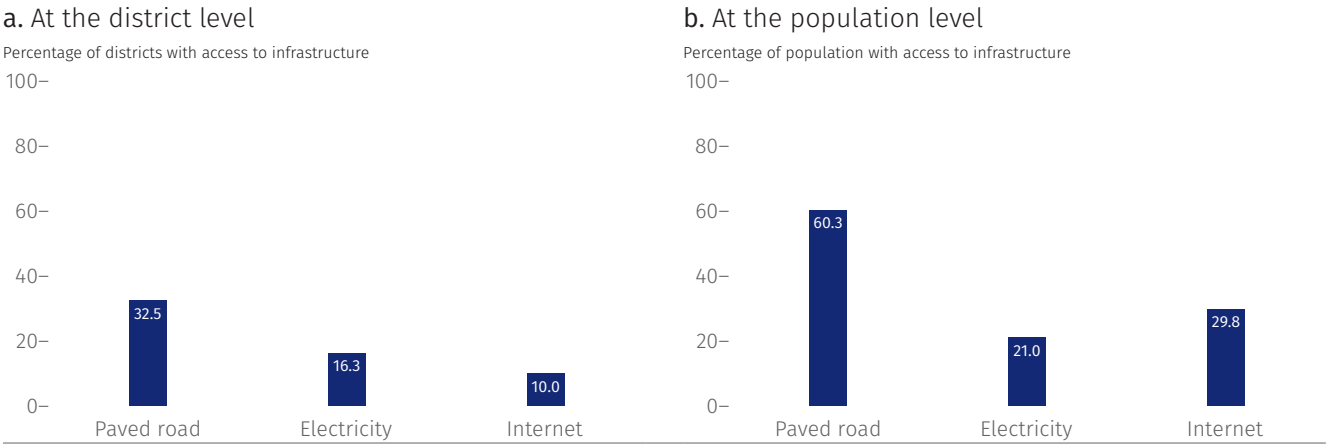
Figure 5.4: Access to infrastructure in Chad (2014)



Note: Authors' calculations using data sources listed in previous section.

of the 80 locations—districts in Nigeria, communes in Cameroon and Chad—have a paved road, 16 percent access to electricity, and 10 percent access to internet. Only half of the population has access to a paved road, 20 percent to electricity, and 30 percent to the internet broadband.

Figure 5.5: Access to infrastructure in the Lake Chad region



Note: Authors' calculations using data sources listed in previous section. The Lake Chad area is defined as the area depicted in Figure A5.20 around the lake. The left graph shows the percentage of districts (admin 2 for Nigeria, admin 3 for Chad and Cameroon), the right graph the percentage of population using the 2015 district population.

5.3 Empirical Strategy and Results

5.3.1 Ordinary Least Squares

The first empirical strategy uses panel ordinary least squares (OLS) regressions, which includes year and country fixed effects and a battery of initial district-level controls. The OLS specification is:

$$Sector_{i,c,t} = \alpha + \beta^{R}\, Paced\ Road_{i,c,t} + \beta^{E}\, Electricity_{i,c,t} + \beta^{I}\, Internet_{i,c,t} + \Upsilon^{RE}\, Paved\ Road_{i,c,t} * Electricity_{i,c,t} + \Upsilon^{RI}\, Paved\ Road_{i,c,t} * Internet_{i,c,t} + Controls_{i,c,t} + FE + \varepsilon_{i,c,t} \qquad (5.3.1)$$

$Sector_{i,c,t}$ is the share of employment in agriculture, manufacturing or services for district i in country c, at year t. The shares are normalized and equal to one. $Paved\ Road_{i,c,t}$ is a dummy variable that takes a value of one if location i in country c contains a paved road at year t. $Electricity_{i,c,t}$ is a dummy variable that takes a value of one if location i in country c has more than 50 percent of its population with lights at night at year t. $Internet_{i,c,t}$ is a dummy variable that takes a value of one if location i in country c has a node on the internet backbone fiber network at year t. $Paved\ Road_{i,c,t} * Electricity_{i,c,t}$ captures the interaction of the road and electricity infrastructure, and $Paved\ Road_{i,c,t} * Internet_{i,c,t}$ the interaction of the road and internet infrastructures. We add interaction effects between the dummies to better understand the complementarities between infrastructures. We do not include an interaction effect for electricity and internet as access to internet is assumed to rely on electricity access. $Controls_{i,c,t}$ represents the additional location-specific controls, which include initial district population, access to a main city, land size, distance to the coast, distance to the border, access to a city of more than 50,000 inhabitants, temperature, and elevation. FE is the year and country fixed-effects. The coefficients β capture the correlation between access to a type of infrastructure on the different sectoral employment shares, while the coefficients Υ capture the infrastructure interaction terms.

We run two other specifications. First we include a specification to study labor participation where the dependent variable is not the normalized sectoral share but the share of non-working individuals. Second, we use variables of usage rather than presence of hard infrastructure to compare the results.

$$Employment_{i,c,t} = \alpha + \beta^{E}\, Electricity_{i,c,t} + \beta^{C}\, Car_{i,c,t} + \beta^{M}\, Motorcycle_{i,c,t} + \beta^{LP}\, LandPhone_{i,c,t} + \beta^{MP}\, MobilePhone_{i,c,t} + \beta^{I}\, Useofinternet_{i,c,t} + Controls_{i,c,t} + FE + \varepsilon_{i,c,t} \qquad (5.3.2)$$

with $Electricity_{i,c,t}$ the percentage of respondents in location i with access to electricity as indicated by the household, $Car_{i,c,t}$ the percentage owning a car, $Motorcycle_{i,c,t}$ the percentage owning a motorcycle, $LandPhone_{i,c,t}$ the percentage owning a land phone line, $Mobilephone_{i,c,t}$ the percentage owning a mobile phone, and $Useofinternet_{i,c,t}$ the percentage using internet. $Employment_{i,c,t}$ can be either the sectoral share or the labor force participation share.

There are several identification challenges that we have identified. Infrastructure investments are likely endogenously allocated with respect to the outcomes of interest. Given the high cost of infrastructure investments, conscious allocation decisions are to be expected, for example by targeting high growth potential locations or politically demanded locations. Finally, measurement error in the right-hand side variables may lead to attenuation bias, for example due to inaccurate timing information of infrastructure expansion or imprecise historic road and grid maps. Measurement errors which are expected to be large in this case, lead to an OLS estimate biased towards zero. In the next section, we present results from OLS regressions, keeping in mind that they do not represent causality. We explore an instrumental variable (IV) strategy in section 3.2 using instruments for paved roads and electricity access only.

5.3.1.1 OLS Results

This section reports results for the unbalanced panel of districts that include at least one EA. We first estimate local average associations of the three infrastructure investments—roads, electricity, and internet—and the interaction between these investments on sectoral employment at the district-year level. Then we analyze the within-country heterogeneity in structural transformation across districts.

5.3.1.2 Average Effects

We start with a regression that includes all countries from the Lake Chad. Then, we compare the results by country revealing some heterogeneity in responses. Throughout, standard errors are clustered at the district-level, which is the level of the treatment. Agriculture, Manufacturing and Services represent the sector shares that add up to one. The 'Non-Working' column represent the share of active population reporting not working at the moment of the interview.

All countries. Access to electricity is associated with a transformation away from agriculture in the Lake Chad region. Table 5.4 reports the results of pooling together data from Nigeria, Cameroon, and Chad. Having access to electricity at the district level is associated with a 20.8 percentage-point reduction in the employment share of agriculture, a 8.5 percentage-point increase in the employment share of manufacturing, and a 12 percentage-point increase in the employment share of services. Access to internet is associated with a decrease in the share of employment in agriculture and an increase in the share of services, but the coefficients are not significant. Access to a paved road is significantly associated with a transformation away from agriculture. Having access to a paved road at the district or commune level is associated with 4 percentage-point increase in the employment share of manufacturing, and a 2 percentage-point increase in the employment share of services. Table A5.2 in the appendix presents the results using the dummy variable that captures electricity access based on the grid expansion for comparison.

Table 5.4: Nigeria, Cameroon, Chad

	Agriculture	*Manufacturing*	*Services*	*Not working*
Paved road	-0.0580**	0.0387**	0.0207+	0.0422**
	(-3.43)	(4.96)	(1.70)	(5.82)
Internet	-0.0791	0.00545	0.0674	0.0134
	(-1.58)	(0.34)	(1.63)	(0.68)
Electricity (>50p)	-0.208**	0.0849**	0.126**	0.0699**
	(-6.68)	(4.70)	(5.70)	(5.21)
Road + Internet	0.0288	-0.0122	-0.00946	-0.0285
	(0.57)	(-0.73)	(-0.22)	(-1.39)
Road + Electricity	-0.00994	-0.0126	0.0199	-0.0811**
	(-0.32)	(-0.68)	(0.89)	(-5.88)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.403	0.346	0.420	0.157
N. of observations	3,041	3,041	3,041	3,041

Notes: t statistics in parentheses; + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$

Table 5.5 shows the results of the analysis when including usages of infrastructure instead of the presence of infrastructure in the district. Both analysis are complementary. The presence of infrastructure does not ensure its full usage by households and represents therefore a low bound of the impacts of infrastructure. The usage represents the higher bound of the estimate of impacts when individuals acquire the goods or services to make the best of these infrastructure. Estimated coefficients are therefore higher when considering the usage rather than the presence of infrastructure. Usage variables in Table 5.5 represent the percentage of respondents that own a certain good or use the services allowed by certain infrastructures.

A 10 percentage-point increase in the number of respondents using electricity is associated with a 3.6 percentage-point decrease in the share of agricultural employment, a 1 percentage point increase in manufacturing and a 2.5 percentage-point increase in services. Having a car, and to a lower extent, having a motorcycle has a large impact on structural transformation. Both the use of mobile and land phones have strong impacts, with a 10 percentage-point increase in the number of respondents using a mobile phone (land phone) associated with a 1.9 (3.3) percentage-point decrease in agricultural employment shares.

Overall the impacts on employment and labor market participation as reported on the last column 'Not working' are mixed.

Around the Lake Chad. We restrict our analysis to the regions neighboring the Lake Chad at the intersection of Chad, Cameroon and Nigeria as shown in Appendix on Figure A5.20. These regions are poorer, less developed and more prone to conflicts. Table A5.5 shows that infrastructure investments there are associated with much larger effects on sectoral shares, especially for electricity and paved roads. Access to electricity and a paved road is associated with a large transformation away from agriculture in the districts directly located around the Lake. Having access to a paved road at the district level is associated with a 13 percentage-point reduction in the employment share of agriculture, an 8 percentage-point increase in the employment share of manufacturing, and

Table 5.5: Nigeria, Cameroon, Chad: the usage perspective, 2008–2018

	Agriculture	*Manufacturing*	*Services*	*Not working*
Electricity (share)	-0.359**	0.109**	0.252**	-0.0257**
	(-23.64)	(15.44)	(19.92)	(-3.47)
Motorcycle (share)	-0.0177	-0.00197	0.0286	0.0140
	(-0.81)	(-0.17)	(1.46)	(1.11)
Car (share)	-0.362**	-0.0517*	0.411**	-0.0498*
	(-8.19)	(-2.11)	(11.03)	(-2.08)
Use of internet (share)	-0.0393	-0.00883	0.0723+	-0.117**
	(-0.80)	(-0.31)	(1.67)	(-3.79)
Mobile phone (share)	-0.189**	0.0909**	0.0942**	0.0667**
	(-6.49)	(6.35)	(3.69)	(3.08)
Land phone (share)	-0.334**	-0.000578	0.345**	0.179**
	(-3.22)	(-0.01)	(3.55)	(3.11)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.605	0.358	0.561	0.157
N. of observations	2,369	2,369	2,369	2,369

Notes: t statistics in parentheses; + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$. All explanatory variables are shares of population between 0 and 1.

a 5 percentage-point increase in the employment share of services. Access to electricity is also associated with large impacts, with a decrease of 14 percentage points for agriculture employment.

By country. In Cameroon, access to electricity is associated with a significant reduction in agriculture employment and increase in employment in manufacturing and services (Table 5.7). Having access to electricity at the district level is associated with a 26 percentage-point reduction in the agriculture employment share, a 21 percentage-point

Table 5.6: Around Lake Chad

	Agriculture	*Manufacturing*	*Services*	*Not working*
Paved road	-0.124*	0.0753*	0.0443	-0.0147
	(-2.05)	(2.39)	(1.11)	(-0.74)
Internet	-0.0583	0.0551*	0.0269	0.0463*
	(-1.02)	(2.03)	(0.65)	(2.16)
Electricity (>50p)	-0.240**	0.0450	0.177**	0.0247
	(-3.13)	(1.66)	(2.75)	(1.00)
Road + Internet	-0.136	-0.0598	0.192+	-0.00410
	(-1.22)	(-1.31)	(1.97)	(-0.13)
Road + Electricity	-0.154	0.143**	0.0348	0.0313
	(-1.32)	(2.74)	(0.42)	(0.73)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.415	0.468	0.540	0.638
N. of observations	123	123	123	123

Notes: *t* statistics in parentheses; + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$. All explanatory variables are shares of population between 0 and 1.

Table 5.7: Cameroon

	Agriculture	*Manufacturing*	*Services*	*Not working*
Paved road	-0.117**	0.0584**	0.0583**	0.0290**
	(-4.77)	(4.68)	(3.66)	(2.59)
Internet	-0.134*	0.0112	0.122**	0.0201
	(-2.46)	(0.52)	(2.63)	(0.60)
Electricity (>50p)	-0.261**	0.212**	0.0489	0.0538+
	(-3.21)	(4.53)	(1.16)	(1.95)
Road + Internet	0.0810	-0.0125	-0.0685	-0.0269
	(1.37)	(-0.53)	(-1.38)	(-0.75)
Road + Electricity	0.0135	-0.114*	0.100.	-0.00549
	(0.16)	(-2.41)	(2.25)	(-0.19)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.410	0.379	0.462	0.103
N. of observations	661	661	661	661

Notes: *t* statistics in parentheses; + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$. All explanatory variables are shares of population between 0 and 1.

increase in the manufacturing employment share and a 5 percentage-point increase in the employment share of services. Access to a paved road is also associated with a significant impact, from agriculture with a reduction of 12 percentage points to manufacturing and services. Finally access to internet is associated with a large impact too, mostly towards the services sector. In terms of combined investments, the combination of both paved roads and electricity seems to support employment in services at the expense of the manufacturing sector. Reduced-form estimates for the usage of infrastructure are reported in Appendix in Table A5.6.

Table 5.8 reports the results of the regression for Nigeria only. Similar to Table 5.4, access to electricity is associated to a large impact. The combined accesses to internet and paved roads as well as paved roads and electricity are associated with a large reduction in the share of agriculture employment, and an increase in the services sector. Reduced-form estimates for the usage of infrastructure are reported in Appendix in Tables A5.7. Table A5.8 reports the results of the regression for Tchad.

5.3.2 Instrumental Variables

In this section we use an instrumental variables identification strategy to deal with the potential endogeneity in the placement of the infrastructure. We instrument both roads and electricity and the interaction terms.

5.3.2.1 IV strategy

We instrument access to the national electricity grid and access to a paved road. Regarding electrification, the instrumental variable relies on four assumptions. Electricity generation must be connected to demand, which comes mostly from the main cities. The sources of energy generation that are identified are the main sources of electricity generation. Third the locations of the supply sources are exogenous to economic geographic development. Finally, the locations between the generation sources and the main demand centers are more likely to be electrified.

Table 5.8: Nigeria

	Agriculture	*Manufacturing*	*Services*	*Not working*
Paved road	0.0137	0.00325	-0.0170	0.0113
	(0.53)	(0.31)	(-0.82)	(1.01)
Internet	0.0122	0.00139	-0.0136	0.0157
	(0.16)	(0.07)	(-0.19)	(0.58)
Electricity (>50p)	-0.151**	0.0319	0.119**	0.00496
	(-3.51)	(1.60)	(3.53)	(0.29)
Road + Internet	-0.0757	-0.00170	0.0773	-0.0378
	(-0.98)	(-0.09)	(1.08)	(-1.36)
Road + Electricity	-0.0431	0.0232	0.0199	-0.0113
	(-1.00)	(1.14)	(0.59)	(-0.63)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.357	0.321	0.282	0.161
N. of observations	2,137	2,137	2,137	2,137

Notes: t statistics in parentheses; + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$. All explanatory variables are shares of population between 0 and 1.

We identify two sources of energy generation that can be used for the IV strategy: dams for hydroelectricity and wind farms. These sources of energy cover most of the sources of electricity generation as reported in Table A14. The main sources of energy supply are hydropower in Cameroon, and gas in Nigeria. Similar to Moneke (2020), we develop an IV which yields a hypothetical electrification status based on a location's proximity to a straight line corridor from electricity generators to the main cities. First, we identify the locations of the electricity generators using two databases, one on dams opening year and another on power plants locations (Platts database). For Cameroon, we use the geolocalized database including all dams in Africa and their year of opening. For Nigeria, we use the global power plant database that includes all power plants per type of energy (hydro, wind, gas, and geothermal) with their capacity and year of commissioning. From the year of dam opening or power plant commissioning onwards, all districts lying along the straight lines connecting the dams or power plants to the main demand centers are considered as having access to electricity. For Nigeria and Cameroon, the main sources of demand vary across time. At the beginning of our panel, all dams in Cameroon have been opened therefore a panel IV is created by varying the sources of demand rather than the supply sources. For Cameroon, we set the threshold of 500,000 inhabitants for a city to be included as a main source of demand for the hydropower supply sources. In 1990, only Douala and Yaounde are included. In 2000, Garoua in the North is included, and in 2015, Maroua is also included. For each year, all districts lying along the straight lines connecting the dams to the cities of more than half million inhabitants will be considered hypothetically electrified. We then identify the main sources of demand in each country. For Nigeria, we include the cities with more than a million inhabitants.

Our IV satisfies the main assumptions of an IV strategy. The choice of location of hydro, gas wind generators can be assumed to be driven by geographic and climatic characteristics of the locations and not by economic activity in the area. The timing of opening can be considered as exogenous as years of delay are common for such projects. The random assignment assumption of the IV would imply that a district's inclusion along a straight line corridor is spatially and temporally as good as randomly assigned.

To instrument for the timing of a district's paved road connection, we find the optimal network to connect all cities with more than 50,000 inhabitants in a least-cost fashion by employing common minimum spanning tree algorithms such as Kruskal's and Boruvka's algorithms. The list of cities with more than 50,000 inhabitants varies over time because of changes in population, which creates a panel of roads for each country.

We now run two-stage least squares (2SLS) on the following specifications, with province and year fixed effects and district-level initial values as controls:[356]

$$\begin{aligned} &Road_{i,t} \#Electricity_{i,t} = \\ &\alpha + \beta^{R} (RoadIV_{i,t} = 1 \;\&\; ElectricityIV_{i,t} = 0) \\ &+ \beta^{E} (RoadIV_{i,t} = 0 \;\&\; ElectricityIV_{i,t} = 1) \\ &+ \gamma^{RE} (RoadIV_{i,t} = 1 \;\&\; ElectricityIV_{i,t} = 1) \\ &+ \beta^{I} Internet_{i,t} + Controls_{i} + FE + \varepsilon_{i,t} \qquad (5.3.3) \end{aligned}$$

with $Road_{i,t} \#Electricity_{i,t}$ being one of the interactions terms between the dummies $Road_{i,t}$ and $Electricity_{i,t}$.

The second stage equation is given by:

$$\begin{aligned} &Sector_{i,t} = \\ &\alpha + \beta^{R,2SLS} (RoadIV_{i,t} = 1 \;\&\; ElectricityIV_{i,t} = 0) \\ &+ \beta^{E,2SLS} (RoadIV_{i,t} = 0 \;\&\; ElectricityIV_{i,t} = 1) \\ &+ \gamma^{RE,2SLS} (RoadIV_{i,t} = 1 \;\&\; ElectricityIV_{i,t} = 1) \\ &+ \beta^{I,2SLS} Internet_{i,t} + Controls_{i,t} + YearFE + \varepsilon_{i,t} \\ &\qquad (5.3.4) \end{aligned}$$

with $Sector_{i,t}$ being the share of employment in agriculture, manufacturing, or services in district i in year t.

356 District level controls variables are interacted with the country dummy such that the effects of distances can only be compared within countries.

5.3.2.2 IV Results

Table 5.9 reports the results for the 2SLS method for Cameroon and Nigeria, that can be compared with the OLS method regression for Nigeria and Cameroon only in Table A5.10 in Appendix. First stages results and weak instrument tests are available on demand. The IV methodology shows stronger effects, especially for combined investments, than the equivalent OLS regression. First access to infrastructure leads to a sharp reduction in the share of non-working individuals, especially when access to electricity is secured. Both access to paved roads and to electricity lead to structural transformation with jobs moving from agriculture to manufacturing and services. The impact of infrastructure investments is even larger when combining investments in roads and electricity, with an additional reduction of 19 percentage points in agriculture employment, mostly redistributed towards services. Access to the fiber backbone also has a significant impact and supports employment in the services sector.

Table A5.11 reports the results of the IV specification for Nigeria only, and Table A5.12 reports the results of the IV specification for Cameroon only. The effects are similar to Table 5.9 when doing the analysis at the country level for Cameroon and Nigeria. For both countries, the combined effects of electricity and roads are dominant to lead to a reduction of agriculture employment and an increase in services and to a lesser extent in manufacturing. The presence of a paved road in Cameroon has led to a larger impact than in Nigeria where the change in access to paved roads has been very small over the period. Access to internet has had a larger impact in Nigeria with respect to Cameroon. Table A5.11 in Appendix reports the results of the IV specification for the Lake Chad region.

Table 5.9: Nigeria and Cameroon: 2SLS method

	Agriculture	*Manufacturing*	*Services*	*Not working*
Paved road=0 × Electricity (>50p)=1	-0.117	0.0499	0.0671	-0.334**
	(-0.64)	(0.84)	(0.39)	(-3.76)
Paved road=1 × Electricity (>50p)=0	-0.0521	0.0412+	0.0110	-0.0376
	(-1.03)	(1.73)	(0.26)	(-1.44)
Paved road=1 × Electricity (>50p)=1	-0.191**	0.0486+	0.142**	-0.0923**
	(-3.32)	(1.86)	(2.86)	(-3.15)
Internet	-0.0335**	-0.00308	0.0365**	-0.00654
	(-3.10)	(-0.59)	(3.85)	(-1.02)
Year + province FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.268	0.130	0.200	-0.122
N. of observations	2,798	2,798	2,798	2,798

Notes: t statistics in parentheses; + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$.

5.4 Welfare Impacts of Infrastructure

We use a model to be able to assess the general equilibrium effects of infrastructure investments and produce counterfactuals for future investments. First, we present the general equilibrium model. Second, we calibrate the model based on the current distribution of population and economic activities. Third we change the trade costs to produce counterfactuals.

5.4.1 The Model

We now present a spatial general equilibrium model based on Moneke (2020). It is characterized by the following broad features. First, locations differ in their productivity, geography and trade links with each other. Second, road investments are assumed to have general equilibrium effects via changes in trade costs and the resulting reallocation of labor across space as in Allen and Arkolakis (2014) and Redding (2016). Third, electrification investments are assumed to have general equilibrium effects via productivity, like models of differential productivity shocks across space such as Bustos et al. (2016). Lastly, we assume the economy to consist of multiple sectors of production such that changes in sectoral employment across locations (i.e. spatial structural transformation) capture an outcome of interest as in Michaels et al. (2011) and Eckert and Peters (2018). Compared to Moneke (2020), we consider a geography that includes several countries which can trade with each other, where additional trade barriers apply for cross-border trade. Workers can move across locations within country but not across countries.

5.4.1.1 Setup

The whole geography consists of many locations, $n \varepsilon N$, of varying land size (H_n) and endogenous population (L_n). Consumers value consumption of agriculture goods, C^T, manufacturing goods, C^M, services, C^S, and land, h. Utility of a representative household in location n is assumed to follow an upper tier Cobb-Douglas functional form over goods and land consumption, scaled by a location-specific amenity shock V_n:

$$U_n = V_n C_n^{\alpha} h_n^{1-\alpha} \qquad (5.4.1)$$

with $0 < \alpha < 1$. The goods consumption index is defined over consumption of each tradeable sector's composite good and services:

$$C_n = [\psi^T (C_n^T)^{\rho} + \psi^M (C_n^M)^{\rho} + \psi^S (C_n^S)^{\rho}] \qquad (5.4.2)$$

assuming consumption of sectoral composite goods to be complementary, i.e.

Consumers exhibit love of variety for both tradeable sectors' goods, C^T and C^M, which we model in the standard CES fashion, where n denotes the consumer's location and i the producer's location, whereas j is a measure of varieties. Consumption of each tradeable sector's good is defined over a fixed continuum of varieties $j \epsilon [0,1]$:

$$C_n^T = [\sum_{i \epsilon N} \int_0^1 (c_{ni}^T(j))^v \, d\, j]^{1/v} \qquad (5.4.3)$$

with v an elasticity of substitution across varieties such that varieties within each sector are substitutes for each other $\sigma = 1/(1-v) > 1$. An equivalent formulation is used for $C^M{}_n$. The following equation provides the classic Dixit-Stiglitz price index over traditional sector goods:

$$P_n^T = [\sum_{i \epsilon N} \int_0^1 (p_{ni}^T(j))^{1-\sigma} d\, j]^{\frac{1}{1-\sigma}} \qquad (5.4.4)$$

On the production side, there are two tradeable sectors from which firms produce varieties that can be traded across many other locations. Production uses labor and land as inputs under constant returns to scale subject to stochastic location.

$$Y_n^i = z^i \left(\frac{L_n^i}{\mu^i}\right)^{\mu^i} \left(\frac{h_n^i}{1-\mu^i}\right)^{1-\mu^i} \quad i=T,M \qquad (5.4.5)$$

where $0 < \mu^i < 1$ and, z^K denotes the sector-location-specific realisation of productivity z for a variety in sector i and location n. Following Eaton and Kortum (2002), locations draw sector specific idiosyncratic productivities for each variety j from a Frechet distribution:

$$F_n^i(z^i) = e^{(-A_n^i z^i)^{-\theta}} \quad i=T,M \qquad (5.4.6)$$

with A^i_n the average sectoral productivity in location n. The shape parameter, θ, determines the variability of productivity draws across varieties in a given location n.

Trade in both sectors' final goods is costly and trade costs are assumed to follow an iceberg structure. Trade costs between locations n and m are denoted as d_{nm}, such that quantity $d_{nm} > 1$ has to be produced in m for one unit to arrive in n. We assume that trade costs are the same across sectors and are symmetric.

Given perfect competition in both production sectors, the price of a given i-sector variety equals marginal cost inclusive of trade costs:

$$p^i_{nm} = \frac{\omega_m^{\mu^i} \; r_m^{1-\mu^i} d_{nm}}{z_m^i} \qquad (5.4.7)$$

with ω_m the wage of a worker and r_m the price of land.

Each location n will buy a given variety from its minimum-cost supplier location m:

$$p^i_{nm} = min\,\{p^i_m\,,\, m \in N\} \qquad (5.4.8)$$

The share of expenditure that the destination location n spends on agricultural sector (and equivalently manufacturing sector) goods produced in origin m is given by:

$$\pi^i_{nm} = \frac{A_m^i \; (\omega_m^{\mu i} \; r_m^{1-\mu i} d_{nm})^{-\theta}}{\Sigma_{k\epsilon N} A_k^i \; (\omega_m^{\mu^i} \; r_k^{1-\mu^i} d_{nk})^{-\theta}} \qquad (5.4.9)$$

Production of non-tradeable services also uses labor and land as inputs, but output is a single homogeneous service. We assume agriculture to be the most and services the least land-intensive sector $\mu^T < \mu^M < \mu^S$.

Within each location, the expenditure share on each tradeable sector's varieties and services depends on the relative (local) price of each sector's (composite) good:

$$\xi_n^K = \frac{(\psi^K)^\kappa \; (P_n^K)^{1-\kappa}}{(\psi^M)^\kappa (P_n^M)^{1-\kappa} + (\psi^T)^\kappa (P_n^T)^{1-\kappa} + (\psi^S)^\kappa (P_n^S)^{1-\kappa}} \quad K\epsilon\{T,M,S\} \qquad (5.4.10)$$

Given the properties of the Frechet distribution of productivities, tradeable sectoral price indices can be further simplified:

$$P_n^i = \gamma[\Sigma_{k\epsilon N} A_k^i \; (\omega_k^{\mu^i} \; r_k^{1-\mu^i} d_{nk})^{-\theta}]^{-1/\theta} = \gamma(\Phi_n^T)^{-1/\theta} \qquad (5.4.11)$$

To arrive at a spatial equilibrium, we provide conditions for land market clearing, labor market clearing and a labor mobility condition. For an equilibrium in the land market, total income from land must equal total expenditure on land, where the latter summarizes land expenditure by consumers, M-sector firms, T-sector firms and S-sector firms. Similarly, labor market clearing requires that total labor income earned in one location must equal total labor payments across sectors on goods purchased from that location everywhere. Finally, we assume that workers can freely move across locations within a country but cannot move across countries. Therefore, free mobility of workers across locations within country implies that the wage earned by workers in a given location after correcting for land and goods prices, as well as a location's amenity value, must be equalized across locations of a same country. The welfare in each location of a same country c is given by:

$$V_{n,c} = V_c = \frac{\alpha^\alpha \; (1-\alpha)^{1-\alpha} V_{n,c} \omega_{n,c}}{[P_{n,c}]^{\alpha/(1-\kappa)} r_{n,c}^{1-\alpha}}, \; \forall n \; \epsilon \text{ country } c \qquad (5.4.12)$$

where $P_{n,c} = (\phi^M)^k (P^M_{n,c})^{1-k} + (\phi^T)^k (P^T_{n,c})^{1-k} + (\phi^S)^k (P^S_{n,c})^{1-k}$. We follow the specification in Moneke (2020) and Michaels et al. (2011) to include the district specific parameter nn;c in the wage so that the welfare can be interpreted as the real income in each location.

5.4.2 Calibration of the Model

We calibrate the model by using some parameters from the literature and by recovering the key productivity parameters and wages to obtain an equilibrium for the current situation. Table A5.15 in the appendix reports the parameters from the literature to calibrate the model which are like the ones in Moneke (2020) applied to Ethiopia. We use the sectoral labor shares from Table A5.15. To recover the productivity parameters, we use the labor market clearing conditions, the land market conditions, and the labor mobility conditions. For each location, the model admits three equations for the three endogenous variables in each location—land market clearing, labor market clearing, and labor mobility condition—which allows to solve for a general equilibrium of the model in terms of its core endogenous variables: wages, land rental rates, and population. Moneke (2020) shows the uniqueness of the equilibrium based on a similar work by Michaels et al. (2011). We obtain a series of $\{A^T{}_n, A^M{}_n, A^S{}_n\} n \epsilon N$ for which the distribution of population, employment, and land is an equilibrium given the current trade costs.

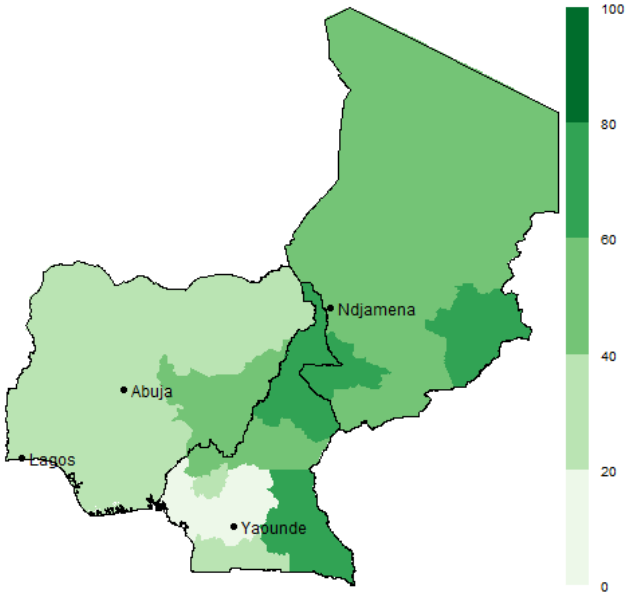
5.4.3 Counterfactuals

We calibrate the model to assess the welfare and spatial impacts of new transport investments. The counterfactual exercise is done in three steps. First, we calibrate the model to obtain the underlying parameters of the model for the baseline situation, without the new investments as explained in the previous section. Second, we update the trade costs based on the new assumptions. Third, we use the model to obtain the new employment shares given the new transport costs, the wage per location, and therefore the real wage given the new equilibrium goods and housing prices.

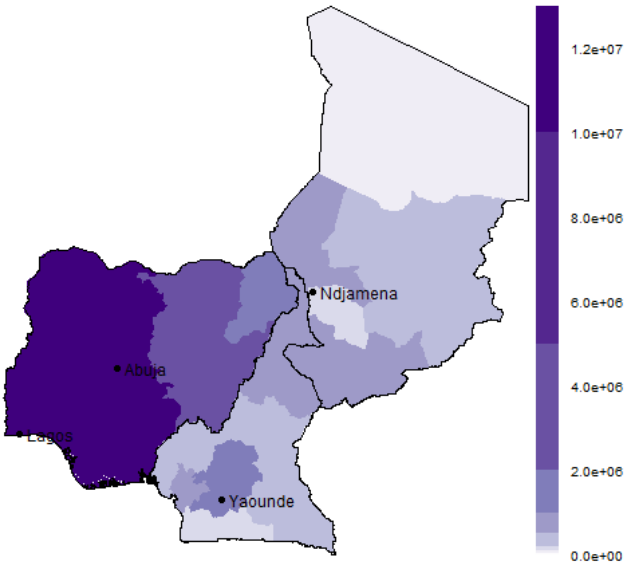
We use the available road networks for each country, with assumptions on speed along the networks given the type and condition of roads that are registered. We rely on additional features such as the type of surface and the condition of the roads. Investments are assumed to increase the speed at which vehicles can travel along the segments that are improved or build new links between locations. We assume trade costs to be iceberg costs such that the costs between location o and destination d are

Map 5.1: Descriptive statistics for the 24 regions in the Lake Chad

a. Share of employment in agricultural sector



b. Total population per subregion



Source: Authors' calculations.

given by $d_{od} = max(1, time^{\tau})$. Border costs are also added to trace costs as detailed in the following sections.

We calibrate the model using spatial data for land, population, and sectoral shares from the sources previously used. Because of the complexity of a 3-sector model to converge in order to recover the initial sectoral productivities, we reduce the spatial disaggregation to fewer locations. Such aggregation also smoothes measurement issues of sectoral employment based on the DHS data. For Lake Chad, we have a total of 24 regions, 8 for Cameroon (adm1 level), 6 for Nigeria, and 8 for Chad. Map 5.1 shows the share of agricultural employment and population for each of these subnational regions.

5.4.3.1 New transport infrastructure in Cameroon and Chad

We investigate the impact of several transport and trade facilitation projects listed in Table 5.10 and represented on Map 5.2 for the part potentially financed by the World Bank and on Figures A5.22 for all the segments financed by different donors assessed in the next section. These projects are part of a comprehensive and continued approach to provide a long-term, reliable, safe and efficient multimodal corridor over the entire 1,800km long stretch between Douala-Ngaoundéré-Koutéré-Moundou-Ndjamena (forthcoming World Bank PAD document). The corridor contributes to improve domestic, regional as well as international connectivity for both countries.

Map 5.2: World Bank investments in rail and road projects in Cameroon and Chad

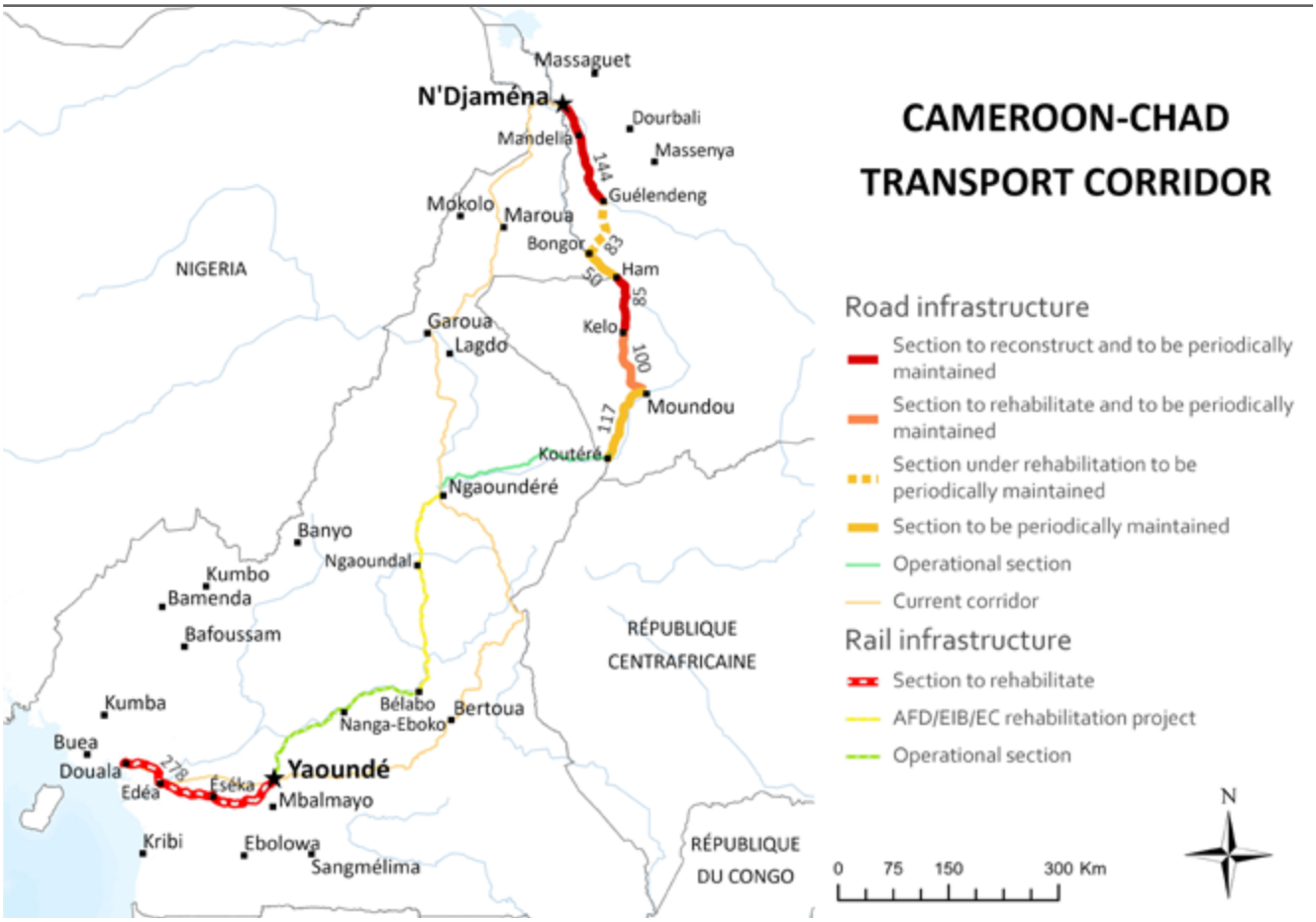


Table 5.10: Summary of counterfactual scenarios

Scenario	Country	Infrastructure	Policies
Baseline			
1	Cameroon	Rail line that is less and less competitive with the road: speed 40km per hour	Platform in Ngadoundere to move from rail to road
	Chad	Corridor (Njamena-Moundou) in bad conditions: speed 30km/h followed by the segment Moundou to the border in good condition	Land border with Cameroon: 30 hours per each border point + administrative costs to trade
Transport infrastructure investments			
2.1	Cameroon Chad	Upgraded road line	
2.2	Cameroon Chad	Upgraded rail line Upgraded road line	
Border investments			
3	Cameroon and Chad	Baseline	from 30 hours to half time: 15 hours
Transport + Border investments			
4.1	Cameroon Chad	Baseline Upgraded road corridor	Half border time Half border time
4.2	Cameroon Chad	Upgraded rail line Upgraded road corridor	Half border time Half border time

Rehabilitation of the rail line in Cameroon. The renovation of the rail line between Ngaoundere, Yaounde and Douala in Cameroon is going through several steps. The World Bank participates in the financing of the Southern part of the project for the segment between Douala and Yaounde, while Agence Française de Développement (AFD) and European Investment Bank (EIB) are planning to finance in 2022 the rehabilitation of the section from Belabo up to Ngaoundere in the North Cameroun. We assume that the two rehabilitations will happen at the same time so we consider both segments. The government is currently planning to renovate the most used segment between Yaounde and Douala, whose condition has deteriorated in the last years. After these projects are completed, the whole existing railway network will be rehabilitated, increasing capacity safety, speed, reliability and efficiency of rail traffic and therefore improving performance of the corridors. We assume very low speed on the whole line in the baseline.

Rehabilitation of road corridors in Chad. There are several historical corridors between Cameroon and Chad. Tensions in the Extreme North have closed the corridors passing by the Northern part of Cameroon and opened the possibilities for other corridors to develop. From Ngaoundére to Ndjamena, the traditional road corridor crosses the region of North Cameroun which is under the threat of Boko Haram, for this reason this road section is today considered as unsafe and unreliable. An alternative road corridor from Ngaoundére to Ndjamena crosses the border near Moundou (second largest city in Chad) and then connect Moundou with Ndjamena (about 600 km). The World Bank is currently assessing a project aiming at rehabilitating this section of the corridor with other donors co-financing as today the road is totally dilapidated while 100% is paved. This project would improve connectivity to the port of Douala, increases domestic connectivity between the main two cities of Chad and improves the regional/ international connectivity of Moudoun. The proposed project covers the whole corridor between Koutere-Moundou-Ndjamena under a phased 10-year long-term Output Performance Based approach that entails rehabilitation works, reinforcement, maintenance and axle load monitoring facilities management.

Complementary policies: Border frictions. We assume that trade across locations from a same country only face transport costs while traders across countries have to wait an additional 30 hours to be able to cross the borders. Given the lack of data, we assume a level of 30 hours by default. In the forthcoming counterfactuals, we add a reduction of half border time to the transport investments.

5.4.3.2 Calibration of the new counterfactual

We use the most recent transport networks from each country as the baseline. We assume a new speed of 70km/h for the new road corridor and reduce the time at the border in some of the scenarios. For the rail corridor, we keep the road network as it is and assume a new direct transport line between Ngaoundere, Yaounde and Douala. New transport times are computed assuming that the previous roads can be used as well as the new rail line, which is more efficient. Stops between the main cities are not permitted. The first section between Ngaoundere and Yaounde is assumed to be 627kms with an average speed of 70km/h.[357] The second section between Yaounde and Douala is assumed to be 261kms with a new average speed of 70km/h.

5.4.3.3 Welfare impacts

We look at the impacts on country GDP and welfare. Welfare differs from income as it also includes differences in prices for goods and housing across locations as well as an amenity from living in different places. First we compute the nominal GDP impacts measured as the total nominal incomes.

$$\Delta GDP_c = \Delta Population_{n,c} \times NominalIncome_{n,c} \quad (5.4.13)$$

with $Income_{n,c}$ the total nominal income in location n of country c.

Second we compute the welfare impacts in each counterfactual and compare it to the baseline welfare. Because we do not allow for mobility across countries, welfare is equalized within each country but not across countries.

$$\Delta Welfare_c = \Delta Population_{n,c} \times V_{n,c} \quad (5.4.14)$$

with $V_{n,c}$ the welfare in location n of country c defined in equation 4.12.

Table 5.11 reports the change in employment share in non-agricultural sectors at the national level from the combined road and rail investments and with the additional border friction reduction. The proposed transport investments are expected to have a marginal impact on structural change away from agriculture at the national level in most countries. When reducing border frictions, Nigeria benefits from a better access to its neighbors to specialize slightly more in non-agricultural activities. Chad tends to specialize more in the primary sector. However most changes will happen between regions within country.

Tables 5.12 and 5.14 show the change in nominal income and welfare (real income) for the three countries when only considering the new road corridor in Chad. Tables 5.13 and 5.15 show the change in nominal income and welfare (real income) for the three countries when considering both the rail and road corridors in Chad and Cameroon. Overall Chad gains the most from the projected investments as it benefits from its own corridor and the corridor in Cameroon. The new transport corridor in Cameroon benefits the most Cameroon when it is accompanied by a significant reduction in border costs. Nigeria benefits from welfare gains through lower prices in the two other countries, but does not benefit from income gains. Tables 5.12 and 5.13 show that most gains come increasing purchasing power due to lower prices.

357 Distance assumptions come from the website rome2rio.com which reports distance per transport mode.

Table 5.11: Road and rail corridors: change of employment share in non-agricultural sectors (in percentage points)

Scenarios	Cameroon	Chad	Nigeria
Transport only	-0.3	0.05	0.03
Transport + Border	0.1	-0.6	1.8

Table 5.12: Road corridor in Chad: Percentage Change in nominal GDP

Scenarios	Cameroon	Chad	Nigeria
Transport only	0	0.1	0
Transport + Border	0	0.7	0

Table 5.13: Road and rail corridors: Percentage Change in nominal GDP

Scenarios	Cameroon	Chad	Nigeria
Transport only	0	0.3	0
Transport + Border	0	0.6	0

Table 5.14: Road corridor in Chad: Percentage Change in Welfare (real income)

Scenarios	Cameroon	Chad	Nigeria	Lake Chad region
Transport only	0.0	0.23	0.02	0.1
Transport + Border	2.25	3.3	2.3	4

Table 5.15: Road and rail corridors: Percentage Change in Welfare (real income)

Scenarios	Cameroon	Chad	Nigeria	Lake Chad region
Transport only	0.5	0.7	0.03	0.8
Transport + Border	2.8	3.7	2.3	4.8

Tables 5.14 and 5.15 show that the welfare gains in the limited Lake Chad region would be relatively larger than at the country level. The region benefits from direct transport investments, especially the road corridor in Chad, and from indirect better connectivity to the rest of Cameroon as well as from the reduction in border delays.

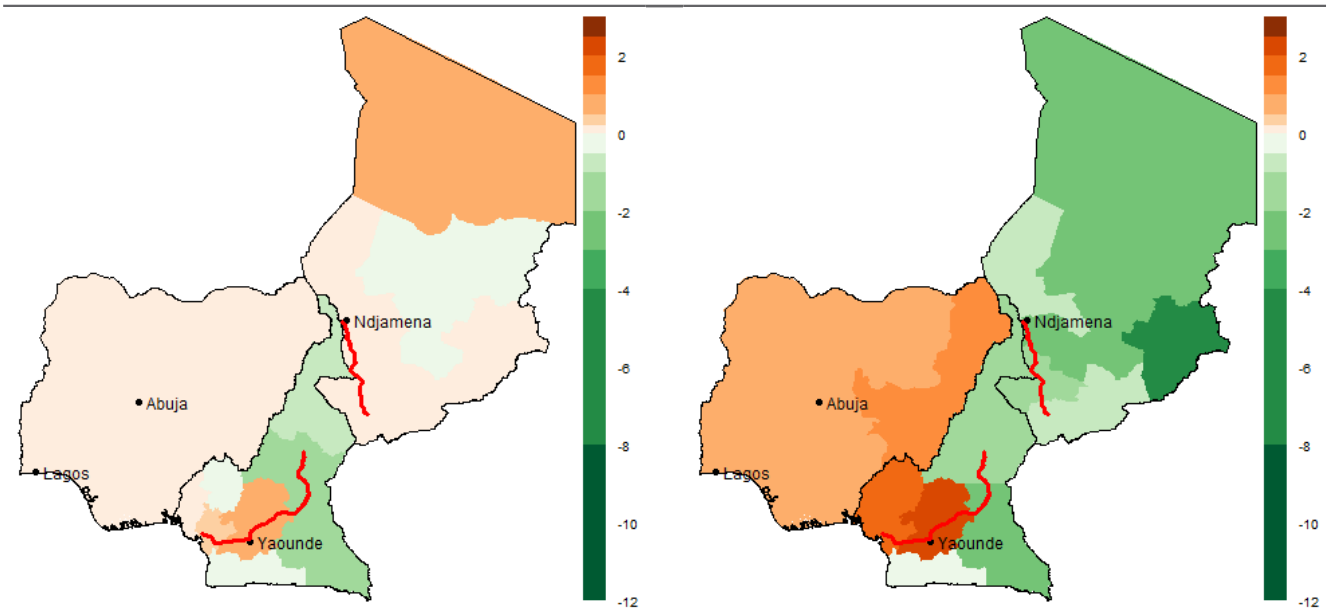
5.4.3.4 Spatial impacts of the road and rail corridors

Maps below report the spatial impacts in terms of change in agricultural employment and welfare changes at the aggregated local level for two scenarios: only with the rail and road transport investments and with reduction in border time.

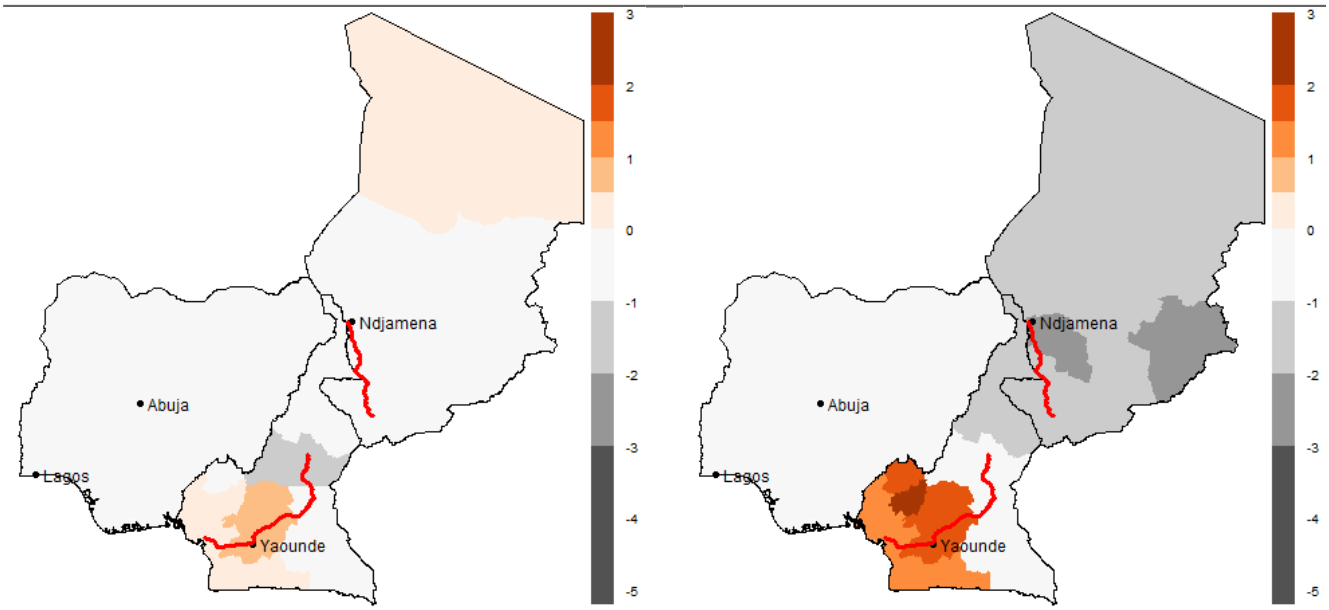
Change in non-agricultural agricultural employment shares. Map 5.3 reports the change in employment at the subnational level. The specialization patterns differ when reducing border frictions or not. Combined transport and border investments increase the specialization of Nigerian regions and the South-Eastern part of Cameroon towards non-agricultural activities. The rest of Cameroon and most Chadian regions specialize more into tradable agricultural activities. Map 5.4 show that it is mostly the South-Eastern parts of Cameroon that will specialize more in manufacturing activities.

Overall, welfare gains, measured as gains in real subnational income, are positive at the aggregate level for all countries but not for all subnational regions. Regional real income, i.e. the sum of real incomes for the whole population of the region, increases for the regions that benefit from new corridors and lower border costs first. When only investing in corridors, some regions lose in terms of regional income, while others gain. When adding border time reduction, the large majority gains from lower trade costs and new regional trade opportunities. As seen from Tables 5.12 and 5.13, most gains come from lower prices and therefore higher purchasing power.

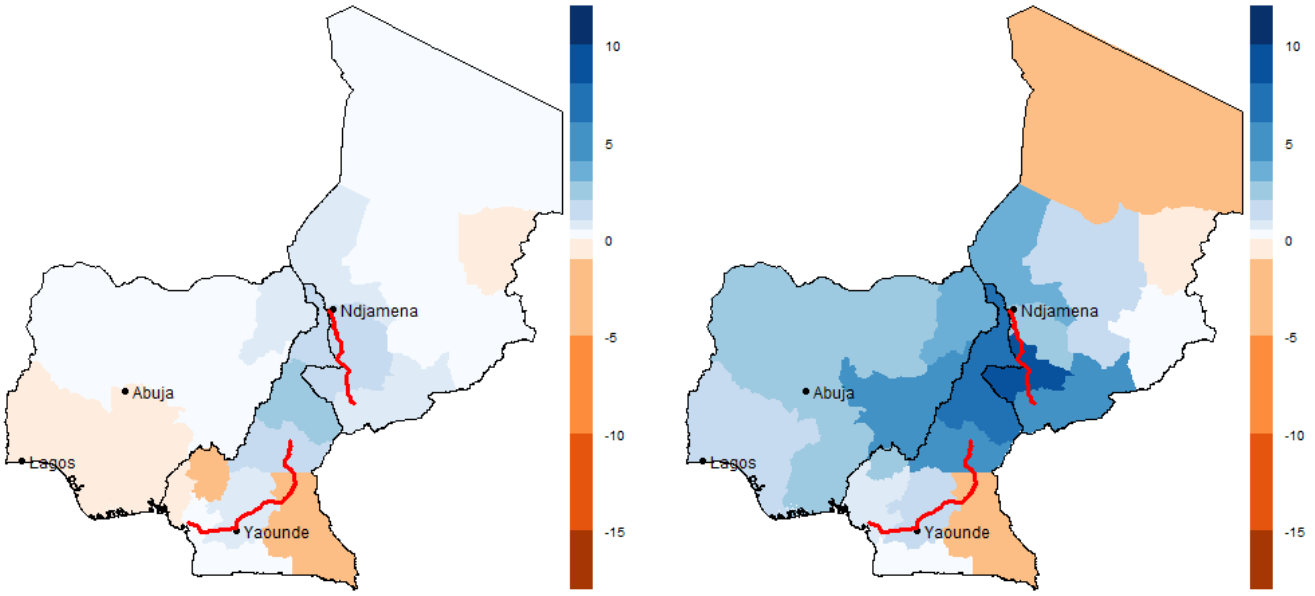
Map 5.3: Change in share of employment in non-agricultural sectors from transport corridor investments (left) with additional border reduction (right) compared to baseline - in percentage points



Map 5.4: Change in the share of employment in manufacturing sectors from transport corridor investments (left) with additional border reduction (right) compared to baseline - change in percentage points



Map 5.5: Regional welfare impacts from transport corridor investments (left) with additional border reduction (right) - percentage change in regional welfare



5.5 Conclusion

This paper investigates how infrastructure—transport, electricity and internet—affects economic development through the channels of sectoral employment and structural change. First, the paper provides estimates of the impacts of past transport, electricity and internet investments in Nigeria, Cameroon and Chad on sectoral employment. Using a series of instruments, we estimate a large impact of infrastructure investments, especially from the combination of paved roads and electricity.

The paper then uses a spatial general equilibrium model to provide estimates of the potential impacts of proposed regional transport corridor projects in the Lake Chad, with a focus on the structural transformation at the regional, county and subnational levels. The analysis also looks at the impact of complementary trade facilitation measures. The analysis shows the importance of such complementary interventions to facilitate regional trade and enhance the benefits of transport corridors. The spatial general equilibrium model developed in the paper does not consider investments in electricity and internet. The plan for future research is to include those infrastructure sectors in the model and link it with the empirical analysis.

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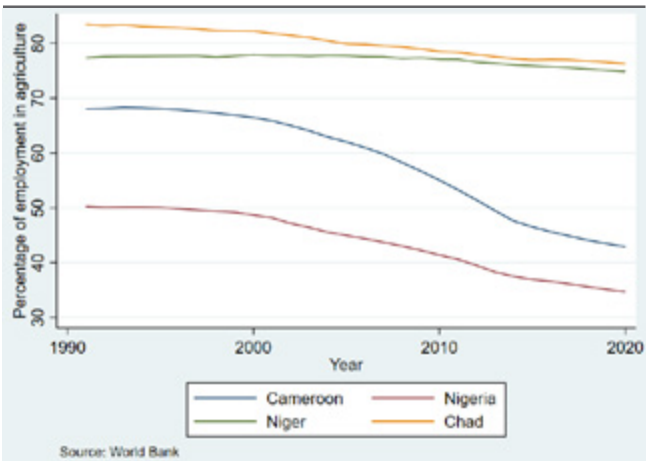
Appendix

A5.1 Employment

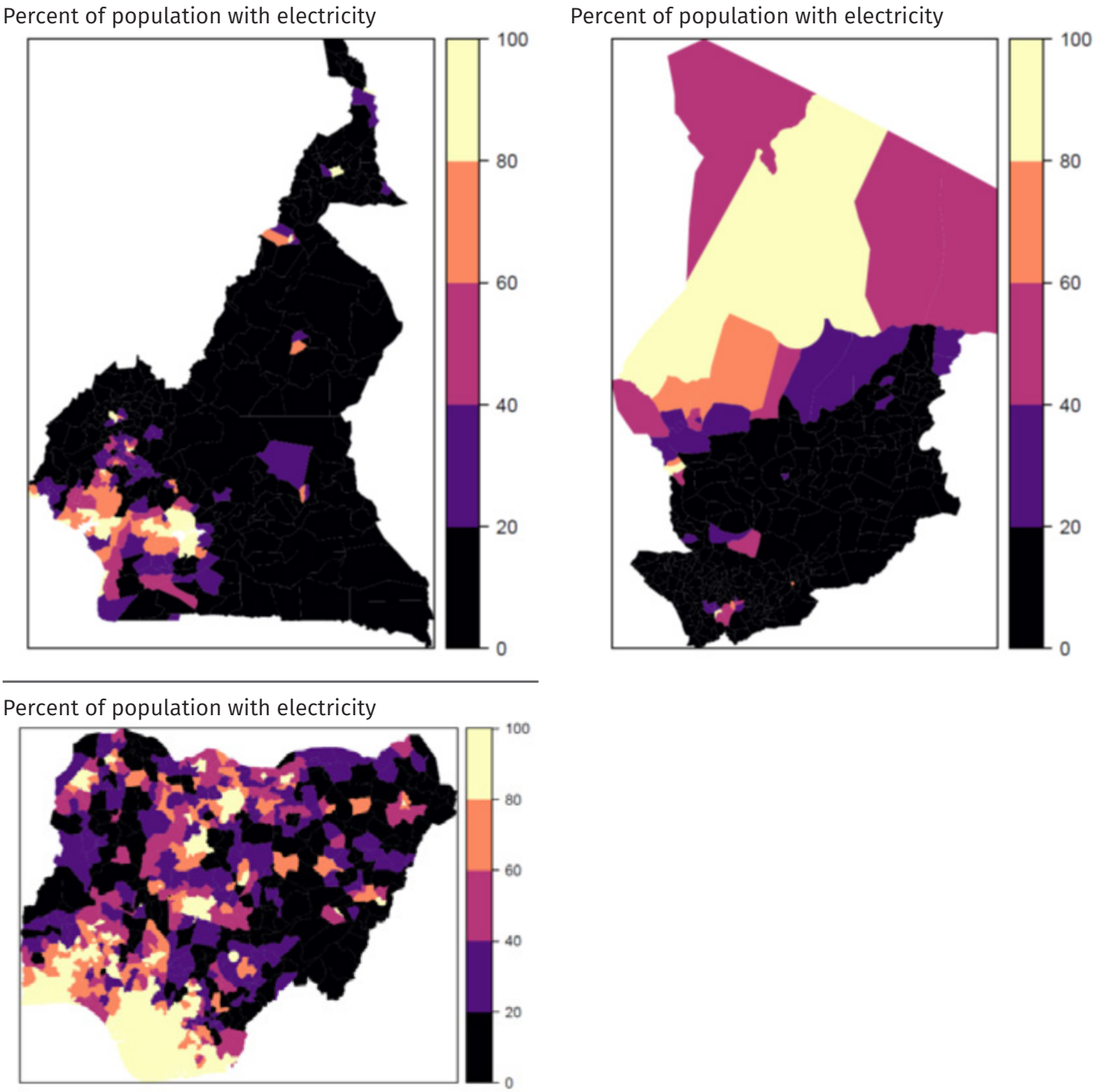
Figure A5.1: Employment in agriculture in the Lake Chad countries



A5.2 Mapping Infrastructure in the Lake Chad

A5.2.1 Measuring electricity access based on Night-Time Lights (2016)

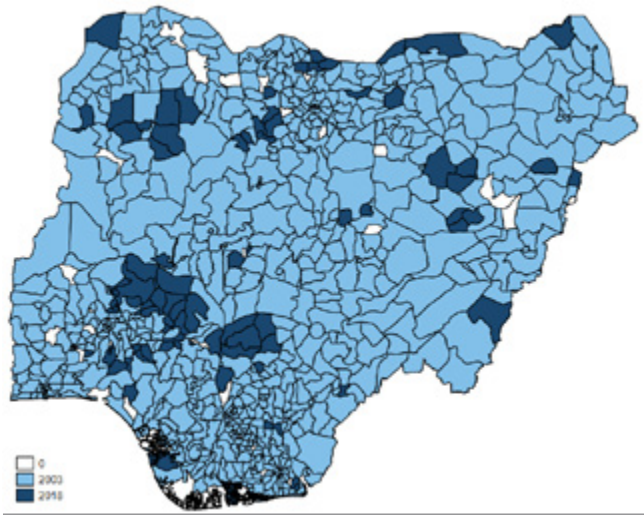
Figure A5.2: Percentage of population with access to electricity (2016)



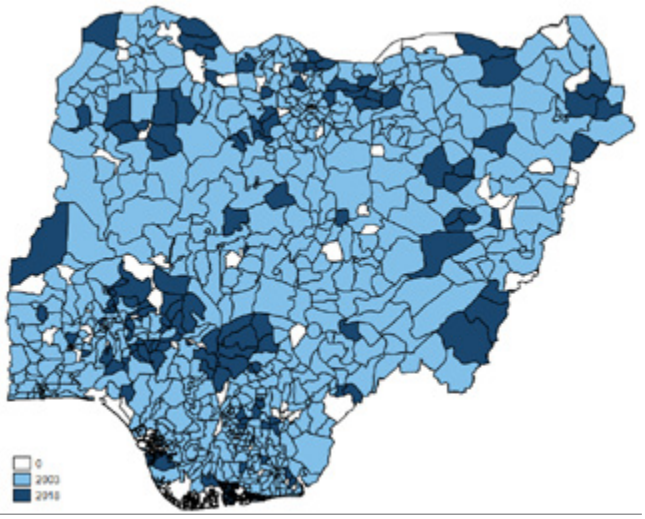
A5.2.2 Nigeria

Figure A5.3: Access to paved roads

a. All

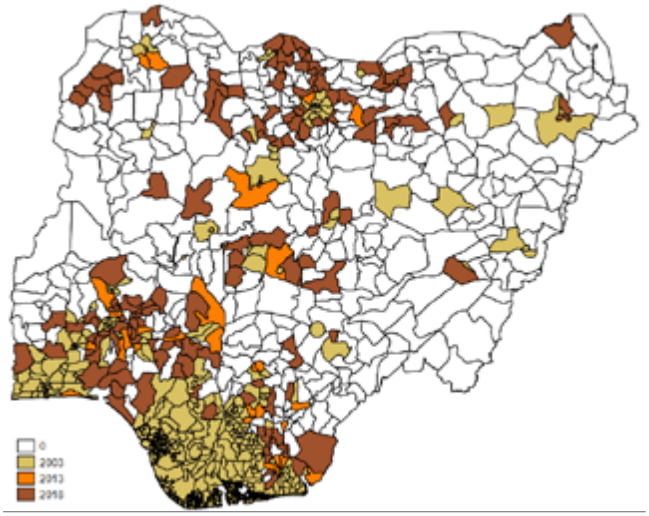


b. In fair or good condition



Note: Data from Foster and Briceno-Garmendia (2010) and Ali et al. (2015). The map represents the year at which access to a paved road is observed. 0 means that no paved road is reported in the latest observed year. 2013 refers to districts with a paved road when observed in 2013 only. 2018 refers to additional districts with a paved road when observed in 2018 compared to 2013.

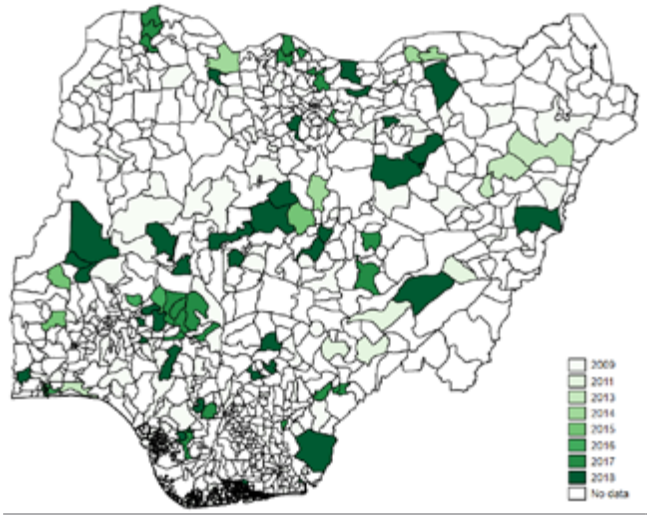
Figure A5.4: Access to electricity



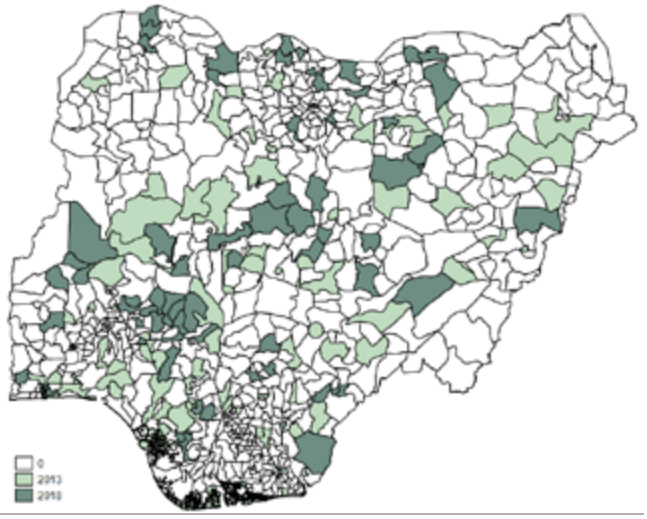
Note: Authors' calculations using Night Time Lights. The mapap represents the year at which at least 50 percent of the population has access to electricity, measured by lights at night. 0 means that no access to electricity is reported in the latest observed year. The earliest year refers to districts with access when observed in that year only. Successive years refer to additional districts which gained access when compared to previous years.

Figure A5.5: Access to internet fibre network

a. From 2009 to 2019



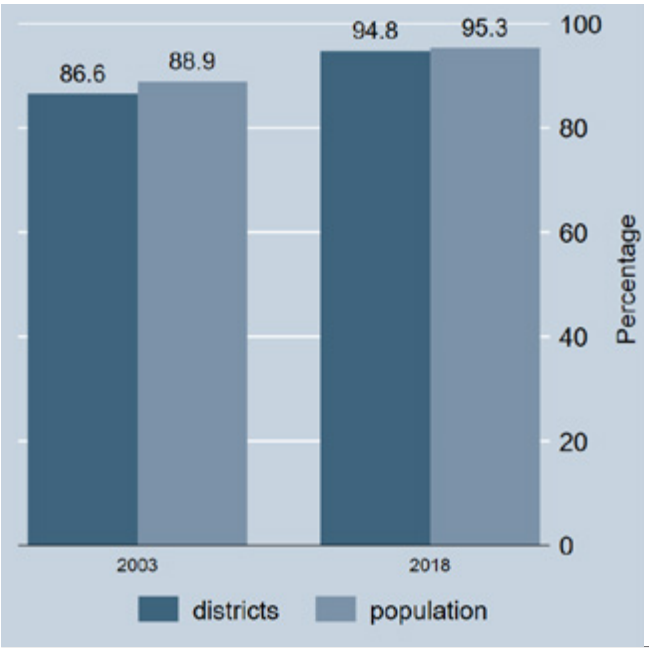
b. Years of interest



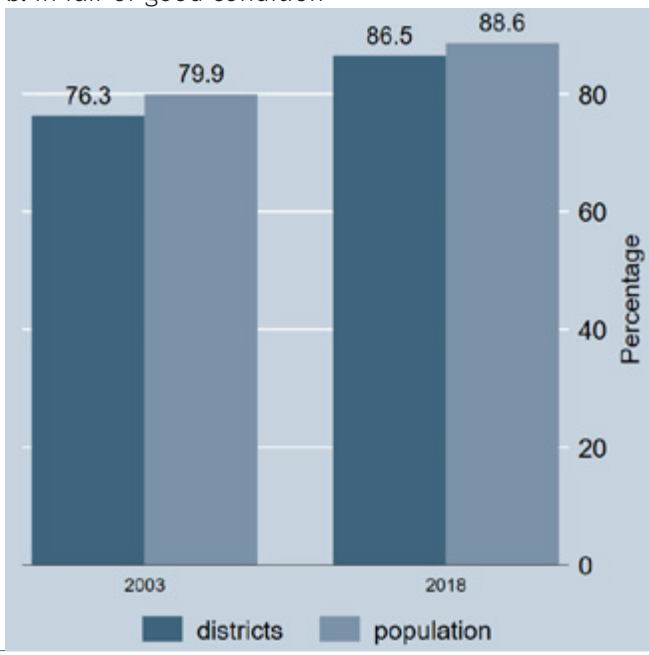
Note: Authors' calculations using Africa Bandwidth Maps. The maps represent access to the fiber network as measured with a node being present in the district. 0 means that no access is reported in the latest observed year. The earliest year refers to districts with access when observed in that year only. Successive years refer to additional districts which gained access when compared to previous years.

Figure A5.6: Percentage of districts and population with access to a paved road

a. All



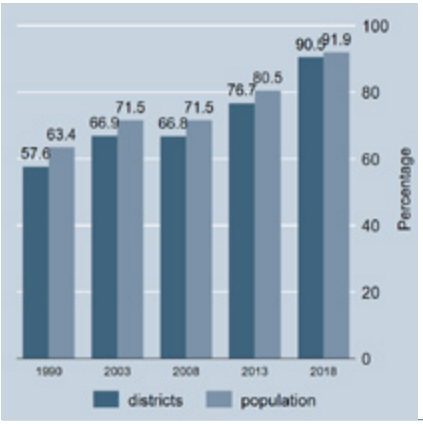
b. In fair or good condition



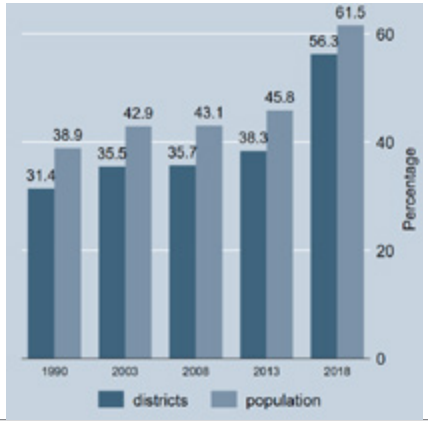
Note: Data from Foster and Briceno-Garmendia (2010) and Ali et al. (2015). The population used for weighted average of access is from GHS 2015.

Figure A5.7: Percentage of districts and population with access to electricity for different thresholds

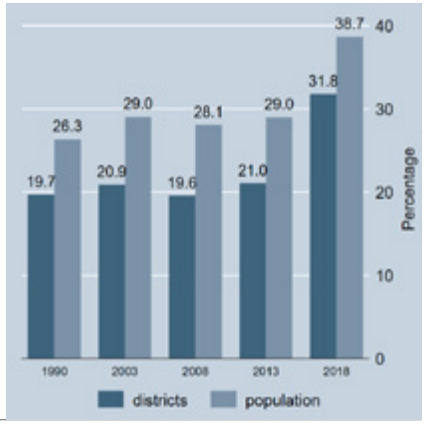
a. Threshold=10%



b. Threshold=50%

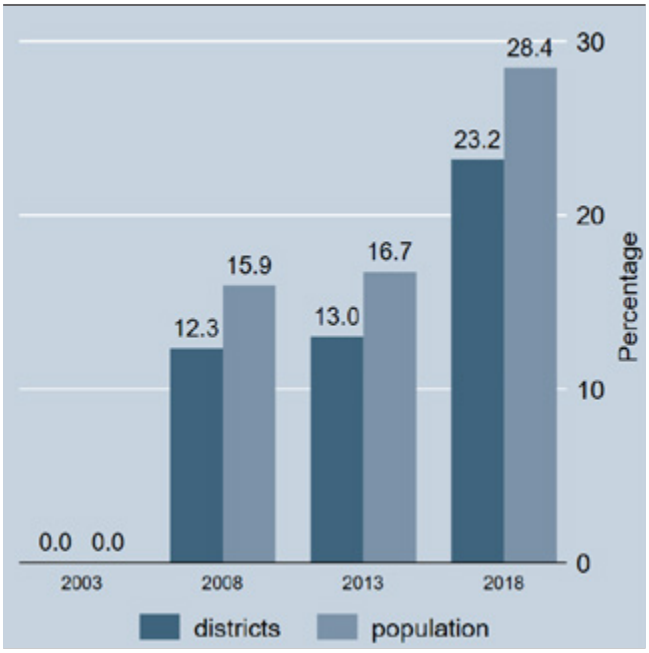


c. Threshold=90%



Note: Authors' calculations.

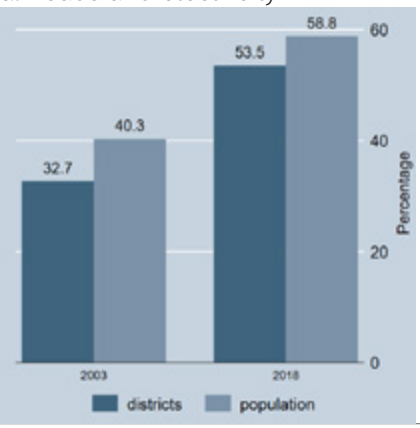
Figure A5.8: Access to internet broadband



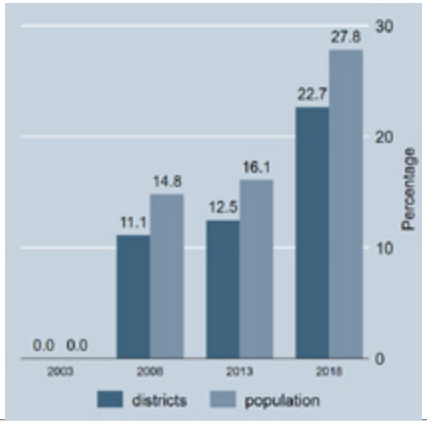
Note: Authors' calculations using Africa Bandwidth Maps.

Figure A5.9: Percentage of districts and population with access to combined infrastructures

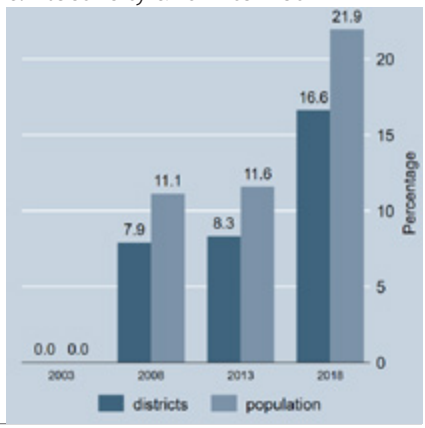
a. Roads and electricity



b. Roads and internet



c. Electricity and internet

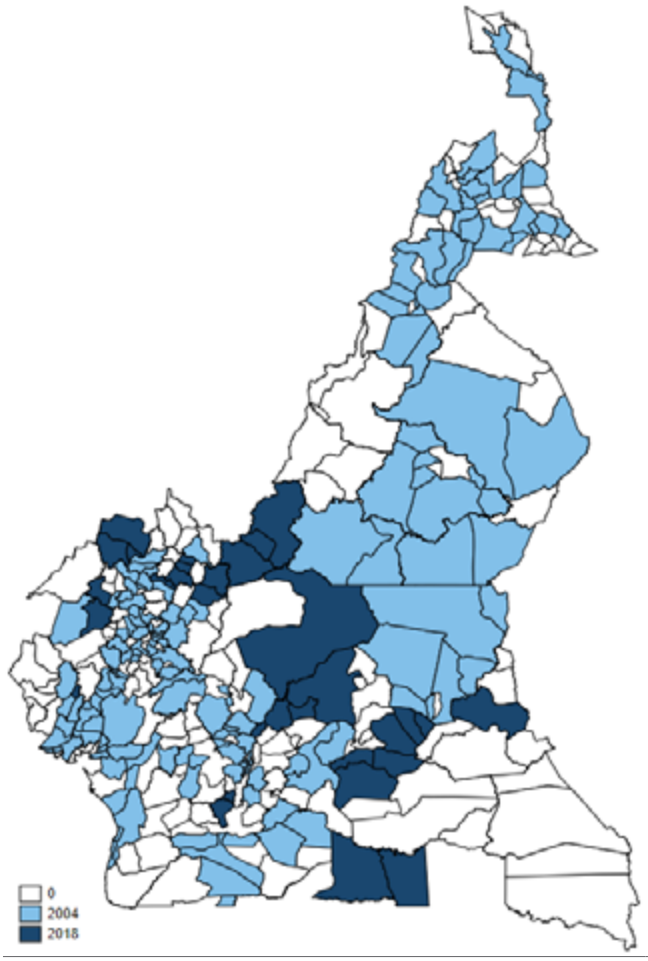


Note: Authors' calculations.

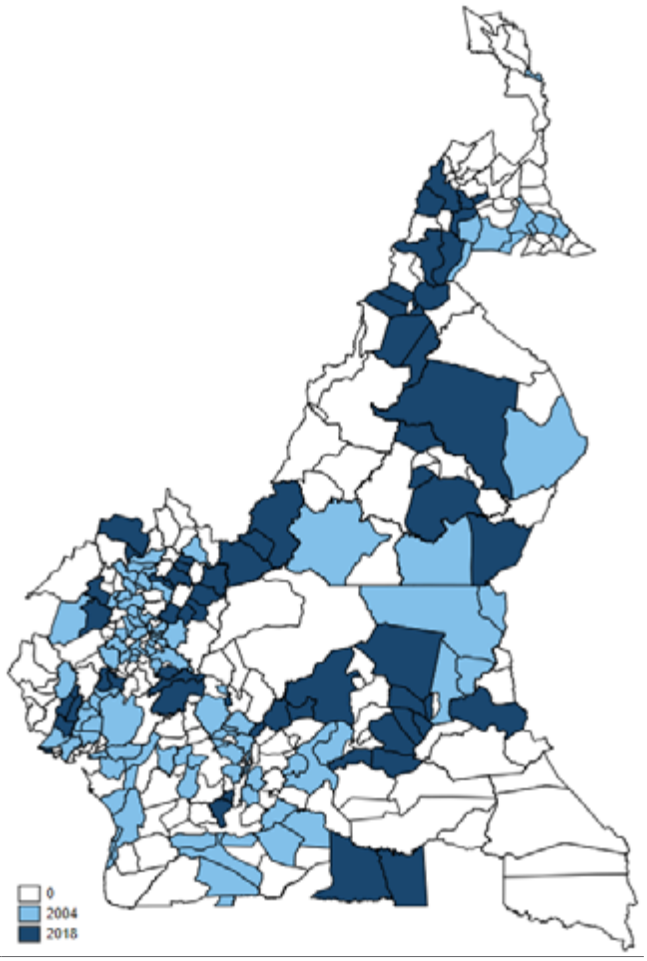
A5.3 Cameroon

Figure A5.10: Access to paved roads

a. All

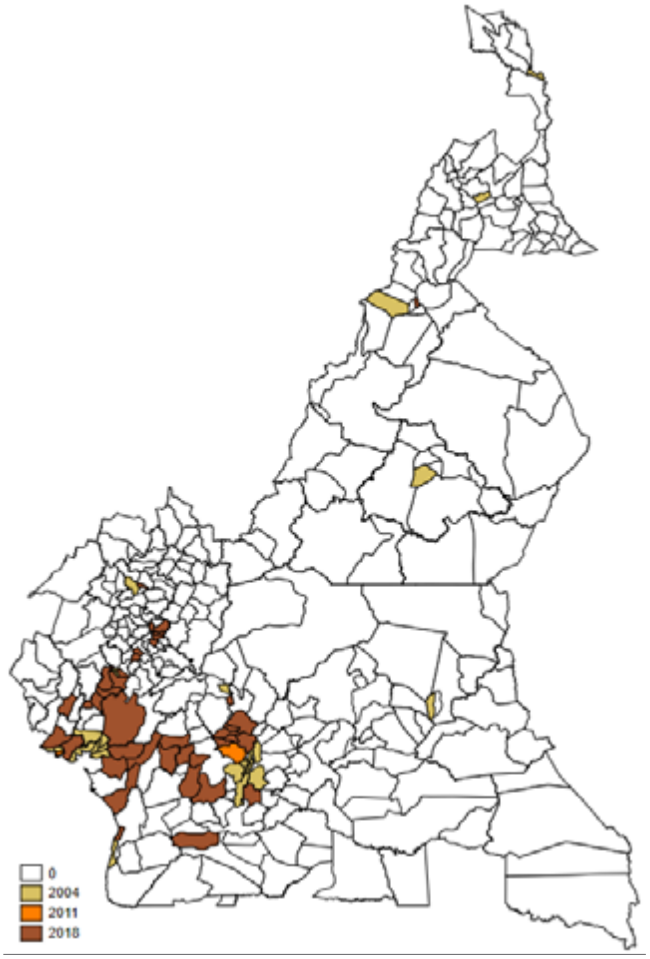


b. In fair or good condition



Note: Data from Foster and Briceno-Garmendia (2010) and government sources. The map represents the year at which access to a paved road is observed. 0 means that no paved road is reported in the latest observed year. 2013 refers to districts with a paved road when observed in 2013 only. 2018 refers to additional districts with a paved road when observed in 2018 compared to 2013.

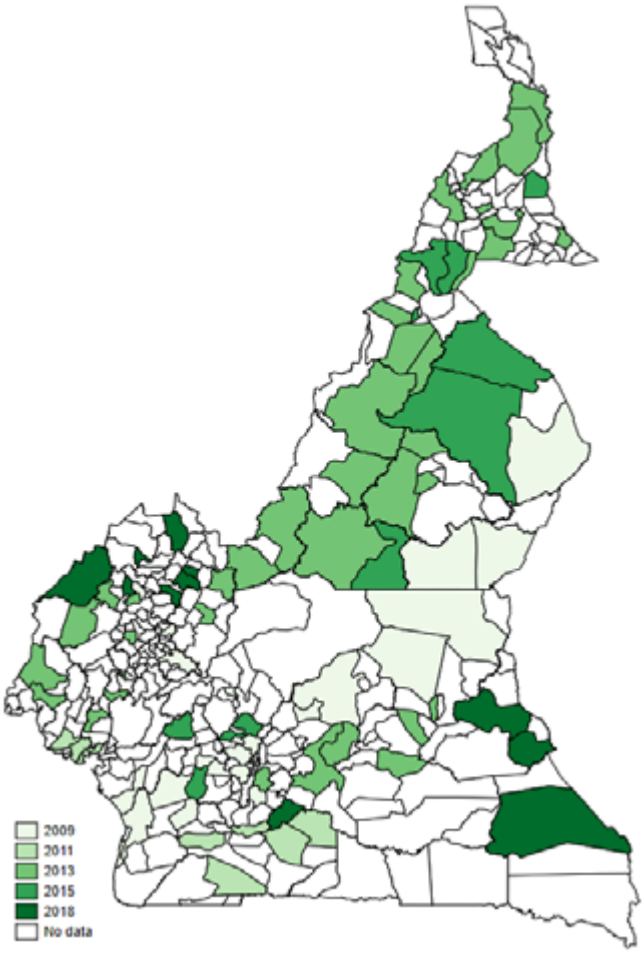
Figure A5.11: Access to electricity



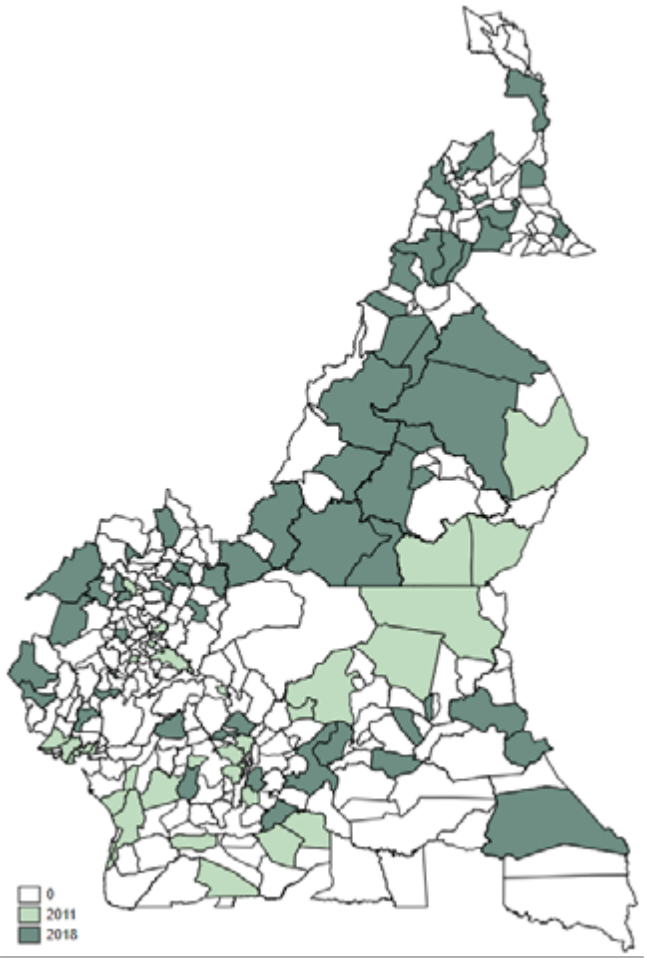
Note: Authors' calculations using Night Time Lights. The map represents the year at which at least 50 percent of the population has access to electricity, measured by lights at night. 0 means that no access to electricity is reported in the latest observed year. The earliest year refers to districts with access when observed in that year only. Successive years refer to additional districts which gained access when compared to previous years.

Figure A5.12: Access to internet fibre network

a. From 2009 to 2019



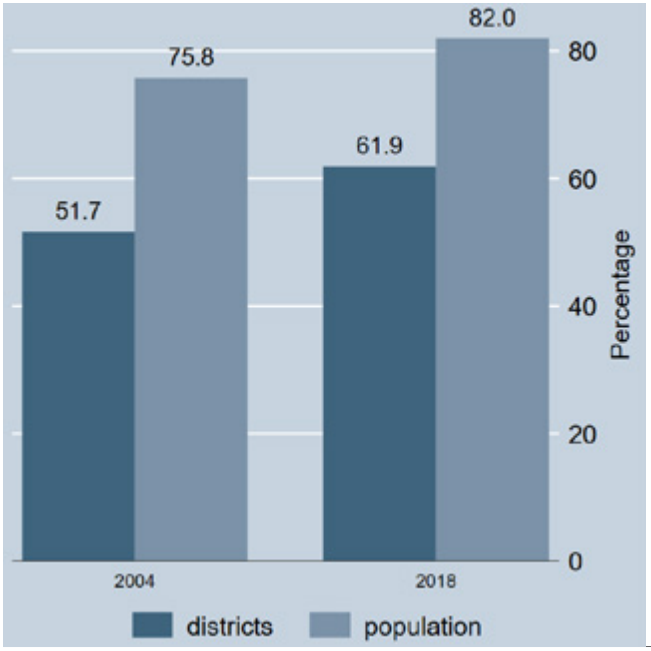
b. Years of interest



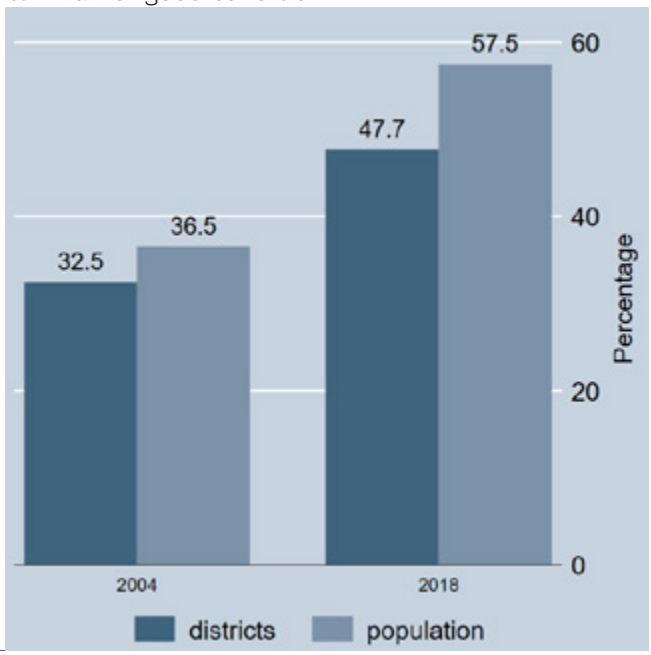
Note: Authors' calculations using Africa Bandwidth Maps. The maps represent access to the fiber network as measured with a node being present in the district. 0 means that no access is reported in the latest observed year. The earliest year refers to districts with access when observed in that year only. Successive years refer to additional districts which gained access when compared to previous years.

Figure A5.13: Percentage of districts and population with access to a paved road

a. All



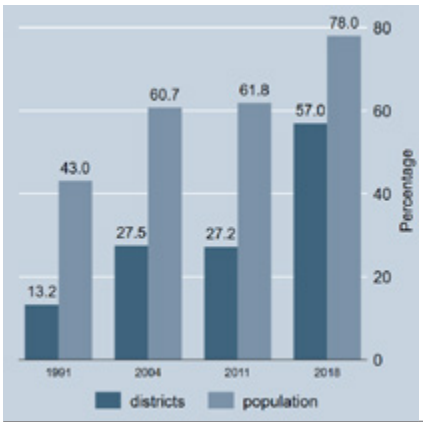
b. In fair or good condition



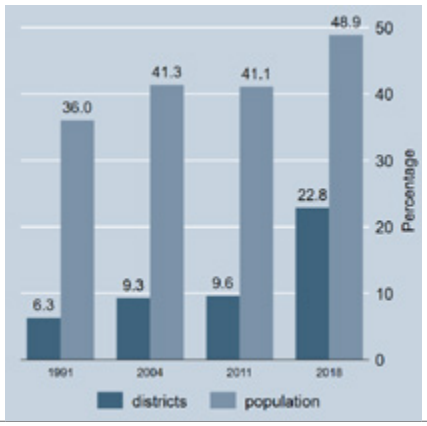
Note: Data from Foster and Briceno-Garmendia (2010) and government sources. The population used for weighted average of access is from GHS 2015.

Figure A5.14: Percentage of districts and population with access to electricity for different thresholds

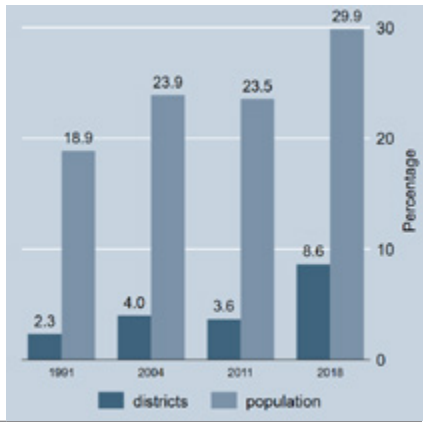
a. Threshold=10%



b. Threshold=50%

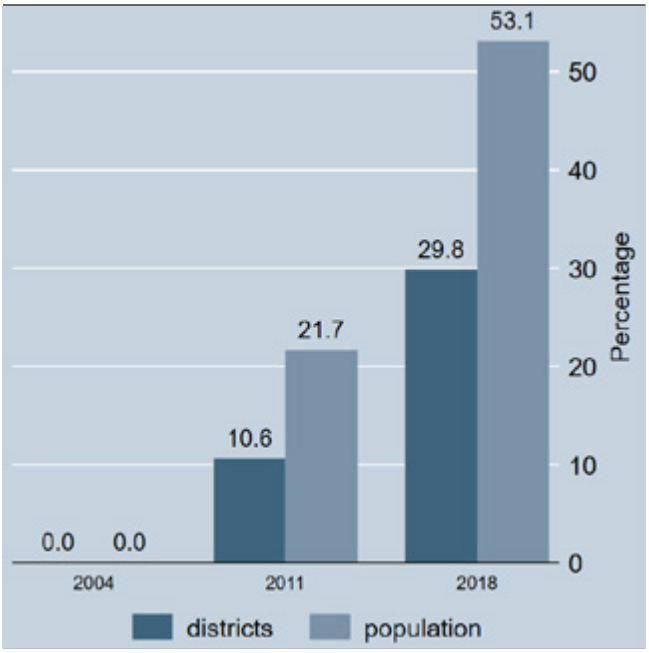


c. Threshold=90%



Note: Authors' calculations.

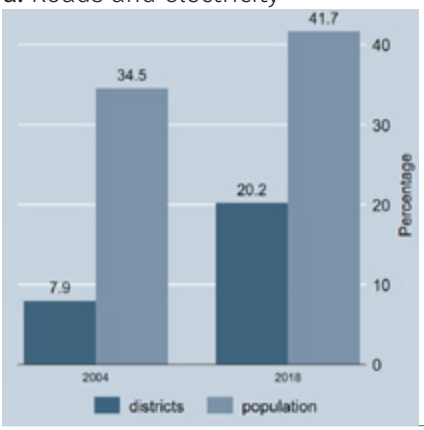
Figure A5.15: Access to internet



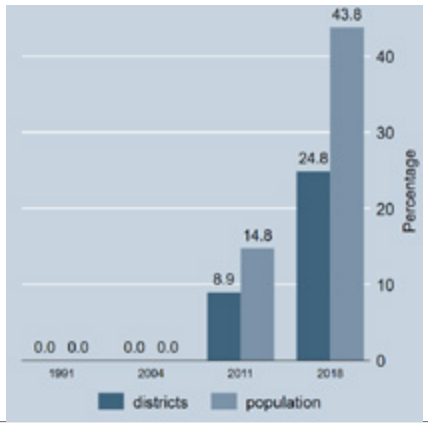
Note: Authors' calculations using Africa Bandwidth Maps.

Figure A5.16: Percentage of districts and population with access to combined infrastructures

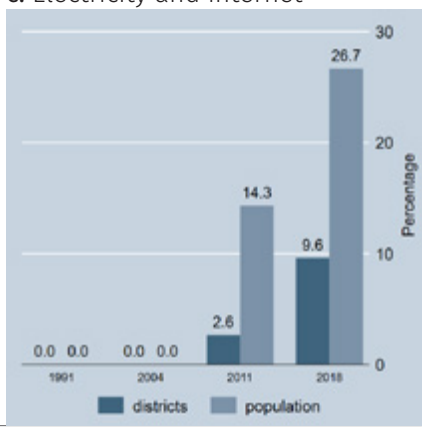
a. Roads and electricity



b. Roads and internet



c. Electricity and internet



Note: Authors' calculations.

A5.4 Chad

Figure A5.17: Access to paved roads and electricity

a. Paved roads

b. Electricity (2014)

Note: Data using government sources and Night Time Lights. The map (b) represents the year at which at least 50 percent of the population has access to electricity, measured by lights at night in 2014. The map (a) represents the year at which at the population has access to a paved road. The map represents the year at which access is observed. 0 means that no access is reported in the latest observed year. Successive years refer to additional districts which gained access when compared to previous years.

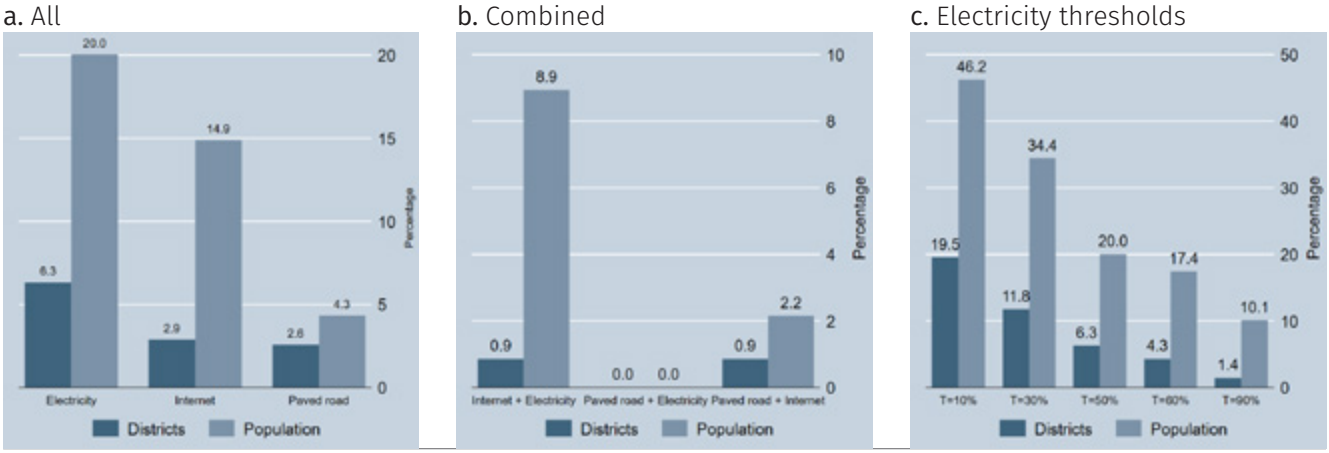
Figure A5.18: Access to internet fibre network

a. From 2009 to 2019

b. In 2014

Note: Authors' calculations using Africa Bandwidth Maps. The maps represent access to the fiber network as measured with a node being present in the district. 0 means that no access is reported in the latest observed year. The earliest year refers to districts with access when observed in that year only. Successive years refer to additional districts which gained access when compared to previous years.

Figure A5.19: Percentage of districts and population with access to infrastructure (2014)



Note: Authors' calculations. The population used for weighted average of access is from GHS 2015.

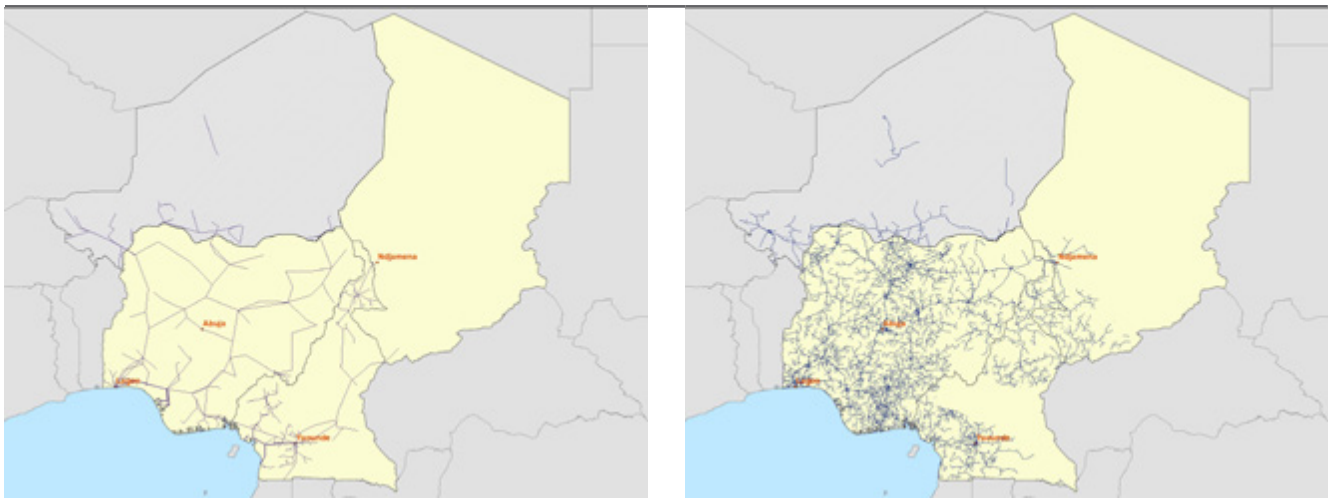
A5.5 Additional Data

Table A5.1: GADM administrative levels

Level	*NGA*	*NER*	*TCD*	*CMR*
adm1	37	8	23	10
adm2	775	36	55	58
adm3	NA	132	348	360

Figure A5.20: Regions around the Lake Chad

Figure A5.21: Electricity grid



A5.6 Regression tables

Table A5.2: Lake Chad (electricity grid)

	Agriculture	*Manufacturing*	*Services*
Paved road	-0.0598**	0.0383**	0.0143
	(-2.82)	(3.94)	(0.91)
Internet	-0.0852+	0.0142	0.0582
	(-1.81)	(0.97)	(1.53)
Electricity grid	-0.0451+	0.0243+	0.0244
	(-1.83)	(1.95)	(1.44)
Road + Internet	-0.00883	-0.00867	0.0290
	(-0.18)	(-0.56)	(0.73)
Road + Electricity grid	-0.0106	-0.000294	0.0176
	(-0.38)	(-0.02)	(0.88)
Year + Country FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.296	0.342	0.347
N. of observations	3,041	3,041	3,041

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.3: Heterogenous effects on agriculture employment, by the initial share of agricultural employment, in Cameroon

	Agriculture q0.25	*Agriculture q0.5*	*Agriculture q0.75*
main			
Paved road	-0.134**	-0.128**	-0.107**
	(-3.34)	(-6.59)	(-4.95)
Internet	-0.0598	-0.0726	-0.141+
	(-0.52)	(-0.71)	(-1.75)
Electricity (>50p)	-0.342**	-0.269+	-0.192+
	(-3.13)	(-1.87)	(-1.71)
Road + Internet	0.0282	0.0551	0.105
	(0.26)	(0.51)	(1.30)
Road + Electricity	0.105	0.0117	-0.0520
	(1.06)	(0.08)	(-0.41)
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared			
N. of observations	661	661	661

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.4: Nigeria, Cameroon, Chad in the period 2008–2018

	Agriculture	*Manufacturing*	*Services*	*Not working*
Paved road	-0.0944**	0.0377**	0.0611**	0.0583**
	(-4.47)	(4.36)	(3.68)	(6.11)
Internet	-0.0706	0.00874	0.0680	0.0162
	(-1.29)	(0.42)	(1.56)	(0.67)
Electricity (>50p)	-0.182**	0.0661**	0.117**	0.0778**
	(-5.38)	(3.37)	(4.60)	(4.81)
Road + Internet	0.0268	-0.0110	-0.0204	-0.0293
	(0.48)	(-0.51)	(-0.46)	(-1.17)
Road + Electricity	-0.0122	0.00351	0.00647	-0.111**
	(-0.35)	(0.18)	(0.25)	(-6.67)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.458	0.341	0.417	0.162
N. of observations	1,817	1,817	1,817	1,817

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.5: Around Lake Chad: the usage perspective, 2008–2018

	Agriculture	Manufacturing	Services	Not working
Electricity (share)	-0.227	0.155	0.165	0.0238
	(-1.01)	(1.44)	(1.13)	(0.50)
Motorcycle (share)	-0.0123	-0.0223	0.0820	-0.0885
	(-0.10)	(-0.37)	(0.85)	(-1.64)
Car (share)	-1.799**	0.432+	0.975+	-0.0441
	(-3.02)	(1.94)	(1.97)	(-0.14)
Use of internet (share)	-0.712	-0.442	0.983	-0.380
	(-0.70)	(-0.77)	(1.52)	(-1.32)
Mobile phone (share)	-0.526*	0.113	0.324*	0.278**
	(-2.52)	(1.22)	(2.10)	(3.03)
Land phone (share)	0.258	-0.0435	-0.217	0.383
	(0.30)	(-0.13)	(-0.34)	(0.93)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.552	0.466	0.540	0.749
N. of observations	96	96	96	96

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.6: Cameroon: from the usage perspective, after 2008

	Agriculture	Manufacturing	Services	Not working
Electricity (share)	-0.413**	0.157**	0.256**	0.0727**
	(-11.60)	(7.69)	(9.42)	(3.98)
Motorcycle (share)	-0.125*	0.0456	0.0799	-0.0116
	(-2.10)	(1.36)	(1.65)	(-0.37)
Car (share)	-0.369**	0.0479	0.321**	0.00608
	(-2.88)	(0.63)	(3.18)	(0.07)
Use of internet (share)	-0.284**	0.123*	0.161*	-0.0947
	(-3.11)	(2.18)	(2.13)	(-1.64)
Mobile phone (share)	-0.220**	-0.0159	0.236**	0.176**
	(-3.13)	(-0.42)	(4.21)	(3.99)
Land phone (share)	-0.244	-0.197	0.441*	-0.140
	(-1.09)	(-1.08)	(2.29)	(-1.00)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.661	0.427	0.604	0.178
N. of observations	442	442	442	442

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.7: Nigeria: from the usage perspective, after 2008

	Agriculture	*Manufacturing*	*Services*	*Not working*
Electricity (share)	-0.323**	0.0827**	0.241**	-0.0458**
	(-18.64)	(10.53)	(16.55)	(-5.59)
Motorcycle (share)	0.0161	-0.00839	-0.00770	-0.00806
	(0.64)	(-0.61)	(-0.34)	(-0.59)
Car (share)	-0.382**	-0.0461+	0.428**	-0.0144
	(-8.56)	(-1.79)	(11.20)	(-0.61)
Use of internet (share)	0.111*	-0.0852**	-0.0259	-0.244**
	(2.14)	(-2.86)	(-0.56)	(-7.65)
Mobile phone (share)	-0.198**	0.103**	0.0951**	0.0551*
	(-6.61)	(6.85)	(3.48)	(2.34)
Land phone (share)	-0.271*	-0.0236	0.295*	0.166**
	(-2.20)	(-0.35)	(2.40)	(2.67)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.572	0.315	0.514	0.176
N. of observations	1,684	1,684	1,684	1,684

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.8: Chad

	Agriculture	*Manufacturing*	*Services*
Paved road	0.0220	0.00467	0.0122
	(0.28)	(0.29)	(0.29)
Internet	-0.113	0.0273	0.0403
	(-0.94)	(1.14)	(1.31)
Electricity (>50p)	0.0595	-0.0145	0.00794
	(0.82)	(-0.86)	(0.31)
Road + Internet	0.111	-0.0590*	-0.0184
	(0.78)	(-2.10)	(-0.37)
Road + Electricity	0	0	0
	(.)	(.)	(.)
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.426	0.339	0.551
N. of observations	243	243	243

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

A5.7 Regression tables: heterogenous impacts

Table A5.9: Heterogenous effects on agriculture employment, by the initial share of agricultural employment, in Nigeria

	Agriculture q0.25	*Agriculture q0.5*	*Agriculture q0.75*
main			
Paved road	0.00808	0.0171	0.0122
	(0.26)	(0.64)	(0.22)
Internet	0.000394	0.0777	0.0696
	(0.00)	(0.96)	(0.66)
Electricity (>50p)	-0.0709	-0.134**	-0.245**
	(-1.06)	(-2.61)	(-3.08)
Road + Internet	-0.0203	-0.109	-0.149
	(-0.18)	(-1.33)	(-1.31)
Road + Electricity	-0.0795	-0.0739	-0.00163
	(-1.14)	(-1.59)	(-0.02)
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared			
N. of observations	2,137	2,137	2,137

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

A5.8 Regression tables: IV strategy

Table A5.10: Nigeria and Cameroon: comparison table (OLS)

	Agriculture	*Manufacturing*	*Services*	*Not working*
Paved road	-0.0683**	0.0406**	0.0292*	0.0337**
	(-3.77)	(4.89)	(2.25)	(4.41)
Internet	-0.0869+	0.0110	0.0682	0.0121
	(-1.68)	(0.65)	(1.58)	(0.51)
Electricity (>50p)	-0.200**	0.0870**	0.117**	0.0481**
	(-5.30)	(3.82)	(4.49)	(3.24)
Road + Internet	0.0277	-0.0132	-0.00571	-0.0292
	(0.53)	(-0.76)	(-0.13)	(-1.21)
Road + Electricity	-0.00481	-0.0238	0.0253	-0.0580**
	(-0.13)	(-1.04)	(1.00)	(-3.89)
Year + Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.396	0.325	0.431	0.114
N. of observations	2,798	2,798	2,798	2,798

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.11: Nigeria - 2SLS method

	Agriculture	*Manufacturing*	*Services*
Paved road=0 × Electricity (>50p)=1	-0.142	-0.0299	0.172
	(-0.77)	(-0.48)	(0.95)
Paved road=1 × Electricity (>50p)=0	-0.0273	0.0202	0.00709
	(-0.47)	(0.76)	(0.14)
Paved road=1 × Electricity (>50p)=1	-0.221**	0.0478+	0.173**
	(-3.24)	(1.67)	(2.86)
Internet	-0.0319**	-0.00275	0.0346**
	(-2.63)	(-0.49)	(3.13)
Year + province FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.224	0.076	0.177
N. of observations	2,137	2,137	2,137

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.12: Cameroon - 2SLS method

	Agriculture	Manufacturing	Services
Paved road=0 × Electricity (>50p)=1	0.479	0.0795	-0.559
	(0.93)	(0.35)	(-1.31)
Paved road=1 × Electricity (>50p)=0	-0.207*	0.130**	0.0773
	(-2.42)	(2.60)	(1.22)
Paved road=1 × Electricity (>50p)=1	-0.321**	0.0478	0.273**
	(-2.95)	(0.75)	(3.37)
Internet	0.0000678	-0.0264+	0.0264
	(0.00)	(-1.75)	(1.01)
Year + province FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.252	0.145	0.055
N. of observations	661	661	661

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.13: Lake Chad area: 2SLS method

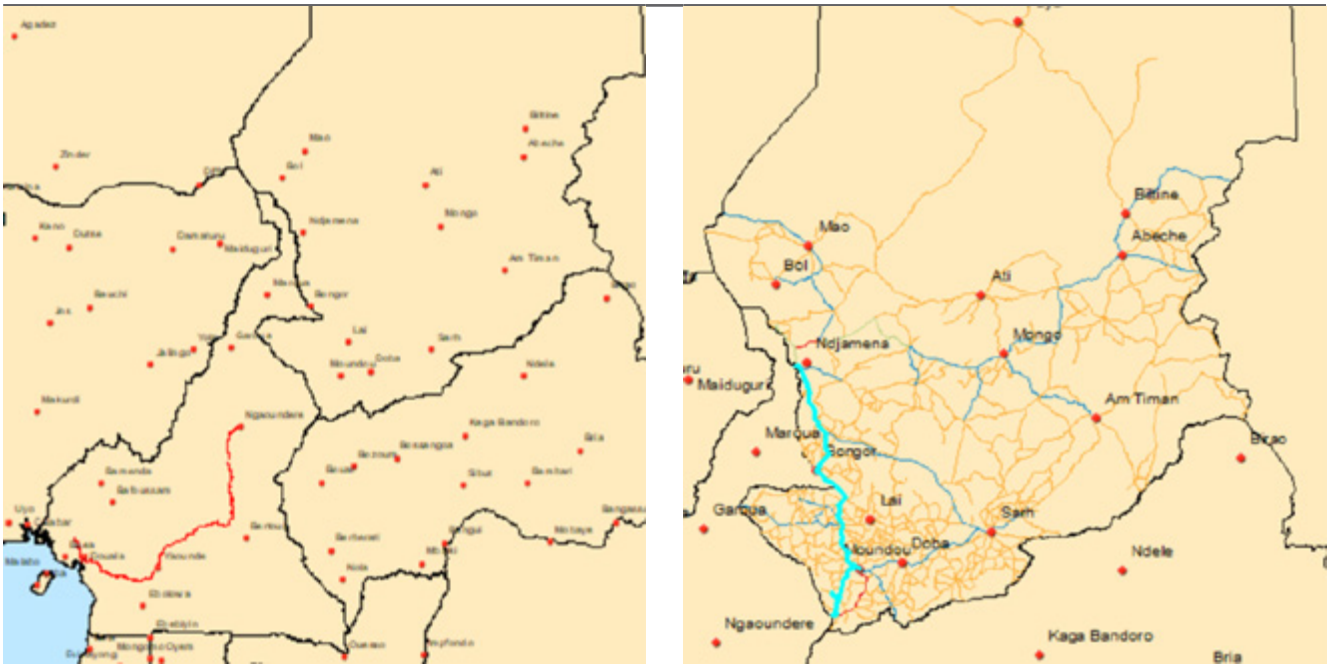
	Agriculture	Manufacturing	Services	Not working
Paved road=1 × Electricity (>50p)=0	-0.133	0.271	-0.138	-0.166
	(-0.48)	(1.21)	(-0.60)	(-1.17)
Paved road=1 × Electricity (>50p)=1	-0.482	0.518*	-0.0363	0.0923
	(-1.58)	(2.11)	(-0.17)	(0.61)
Internet	-0.221**	0.0257	0.195*	0.0225
	(-2.59)	(0.42)	(2.41)	(0.46)
Year + province FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.528	0.099	0.284	0.063
N. of observations	91	91	91	91

t statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A5.14: Energy sources in electricity production (in %)

	1990		2015	
	Cameroon	Nigeria	Cameroon	Nigeria
Hydro	99%	42%	75%	18%
Renewable, excluding hydro	NA	NA	1%	NA
Oil, gas and coal	1%	58%	25%	82%

Figure A5.22: Rail and road investments in Cameroon (left) and Chad (right)



A5.9 Calibration of the Model: Parameters

Table A5.15: Parameters for Structural Estimation

Parameter	*Value*	*Source*	*Description*
σ	4	Bernard et al. (2003)	Elasticity of substitution between varieties
$1-\alpha$	0.25	Data for Ethiopia (HCES)	Expenditure share on land/housing
κ	0.5	Ngai and Pissarides (2007)	Elasticity of substitution across sectors
μ^M	0.82	Moneke (2020) for Ethiopia	Labor share in M-production
μ^T	0.78	Moneke (2020) for Ethiopia	Labor share in T-production
μ^S	0.84	Moneke (2020) for Ethiopia	Labor share in S-production
τ	0.3	Moneke (2020) for Ethiopia	Elasticity of trade cost with respect to distance
θ	4	Donaldson (2018)	Shape parameter of productivity distribution across varieties & locations

Technical Paper 5. Conflict and Climate Change in the Lake Chad Region

Peter Fisker (University of Copenhagen)

6.1 Introduction

Peace and security are basic conditions for economic and social development. Conflict, on the other hand, can reverse years of economic growth and induce long-term harm on almost all aspects of development. For the past decade, the Lake Chad region has been the setting of conflicts between government forces and armed groups, most notably the Boko Haram. Although the intensity of fighting has petered off in recent years, the conflict has spread from Northern Nigeria and now affects all four countries of the region.

Due to the paramount importance of avoiding armed conflict, a large economic literature exists that seeks to find explanations for the onset and prevalence of conflict in developing countries. Blattman and Miguel [2010] list some of the most common theories of conflict including *competition for resources, economic grievances, and the possibility of looting*.

More recently, a strand of literature focuses more on geographic and climatic root causes of conflict. For instance, in a meta-analysis of 55 studies, Burke et al. [2015] find that higher temperatures is the most important climatic factor leading to more interpersonal and intergroup conflict. With a specific focus on civil war in Africa, Burke et al. [2009] warned that projected increases in temperatures could lead to 54 percent increase in armed conflicts by 2030. However, both studies conclude that more research is needed in order to understand the mechanisms behind this relationship as well as investigating the potential adverse effects of climate change. More recently, Eberle et al. [2020] found that a 1 degree increase in temperatures is associated with a 54 percent increase in conflict probability in areas that are home to both herders and farmers and a 17 percent increase in other areas of Africa. A central question is whether the effect goes through an 'income channel' where conflict is ultimately caused by economic downturns due to lower agricultural productivity in periods of warmer temperatures—or whether the effect is somehow physiological, as humans are generally shown, in the medical literature, to be more aggressive when temperatures are higher. Harari and Ferrara [2018] explore the 'income channel' and find that part of the variation in conflict can be explained by a drought index when dis-aggregated to the growing period of the main crops across Africa. However, whether the results would hold without temperatures as an input to the SPEI is unclear.

This paper attempts to shed light on the geographical distribution of conflict and its climatic determinants in the Lake Chad region following a sub-national approach where readily available spatial data is employed at two different units of aggregation: Firstly, 90 second level administrative areas, and secondly, around 5,318 grid cells covering the same region. Exposure to conflict is here defined as the intensity (for districts) or incidence (for cells) of conflict in a given unit in a given year. Parts of the population may not be directly exposed by this definition, but since the units of analysis are relatively small, most will be affected in some ways, for instance by safety concerns when visiting the nearest towns to trade or by the general economic consequences.

The results of the analysis suggest, in line with the literature mentioned above, that temperature anomalies do have a positive impact on conflict across districts, cells and years. It also shows that negative NDVI (Normalised Difference Vegetation Index) anomalies are associated with more conflict—especially in cropland zones and during growing seasons. Rainfall anomalies as well as the SPEI (Standardized Precipitation-Evapotranspiration Index) do not exhibit the same effect on conflict. This could be an indication of measurement errors in these variables—or it could indicate that temperatures and rainfall have different effects on conflict rather than the often-mentioned drought-income channel.

6.2 Data

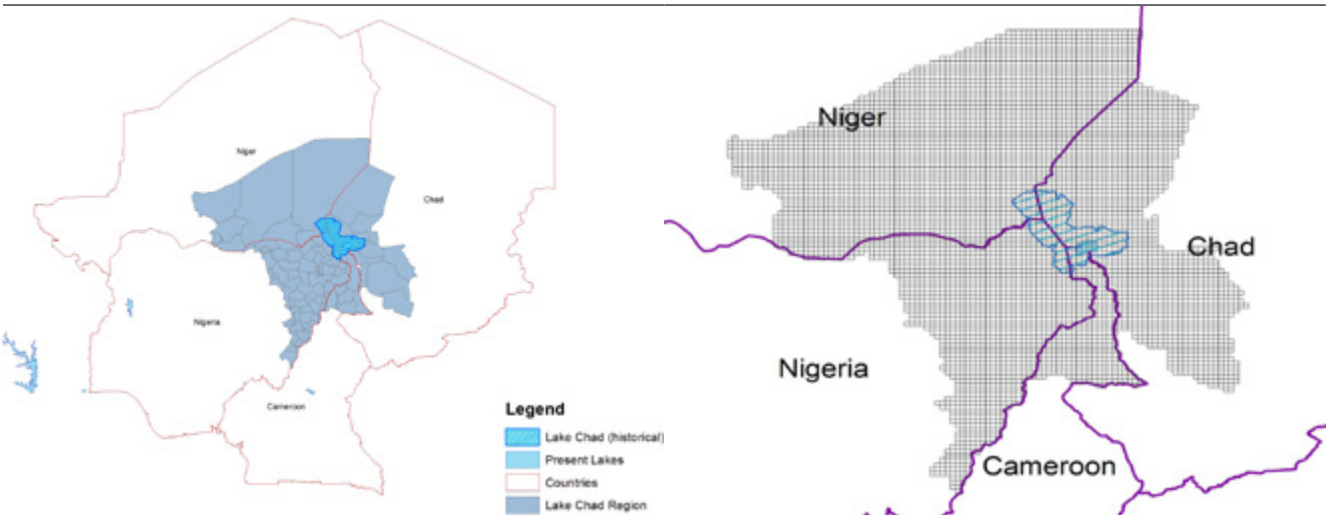
At the core of the analysis lies the geographical delimitation of the Lake Chad region. It comprises 4 countries and a total of 90 districts (2nd level administrative units).

Map 6.1 shows the extent of the Lake Chad region within the four countries of Niger, Chad, Nigeria, and Cameroon. It also shows the units of analysis of this study, namely the districts within the lake region on the left panel and the grid cells on the right. These units are chosen from a practical and methodological perspective. Firstly, they are large enough to cover a meaningful number of satellite data pixels, while small enough for the total number of units to be useful in regression analyses. Secondly, many policies are implemented at this level, so policy-makers will be interested in being able to compare distributions of key variables at district level. The grid cell level is chosen to accompany the district level analysis since it allows for much more variation and more observations due to a higher resolution. Furthermore, since the cells represent little squares, there is no concern about endogenous border locations.

Table A6.1 in the appendix contains a list of indicators included in the analysis, their sources, as well as the spatial and temporal resolution of the raw data. Except for conflict, all data sets included here are originally raster format, but are, for the purpose of the analysis, aggregated to the units of analysis, either using the sum (population, conflict event, and fatalities) or mean (Share of cropland, travel time, rainfall, temperatures, and greenness). While NDVI and temperature data is based on pure (processed) satellite images, data on population, travel time, and precipitation are drawn from secondary sources where the pixel values of the raster data sets are generated from combining various sources of raw data. Conflict risk numbers stand out in this list as it is based on geo-referenced point data from the ACLED database and aggregated to the second level administrative units directly from the recorded latitudes and longitudes of the conflict events.

Data on conflict as well as climate come with a time dimension as well. Here, values are summarized to individual calendar years from 2001 to 2018.

Map 6.1: Extent and units of analysis



6.2.1 Conflict

The conflict data used in this study comes from the Armed Conflict Location and Event Database (ACLED). In this database, conflict events are registered based mainly on local media reports, and geo-referenced. It distinguishes between various types of conflict events, most notably *battles*, *riots*, *protests*, and *violence against civilians*. For each conflict event, the number of fatalities is also reported. In this analysis, both the number of events and the number of fatalities by district-year are used. These two measures of conflict exposure are central outcome variables in the regression analyses presented in the next section.

Table 6.1 includes summary statistics of key conflict variables in the Lake Chad region during the years 2001 to 2018. Of conflict events, battles and violence against civilians are the most widespread types. Nigeria has seen by far the largest number of actual battles, and also the largest number of fatalities. Cameroon is in second place in terms of events, but with a distribution of events leaning more towards acts of violence against civilians. Niger is the most peaceful country in the region over the period.

Figure 6.1 shows the development of conflict over time in the entirety of the Lake Chad Region. Of the four conflict event types, battles and violence against civilians have followed a largely similar pattern over the years while riots and protests are not as commonly reported, but still growing in later years. The sum of conflict fatalities in the region is generally high and volatile, but saw a peak around 2014 and 2015 to around 1,000 per year before dropping again later. Note the logarithmic scale of the vertical axis.

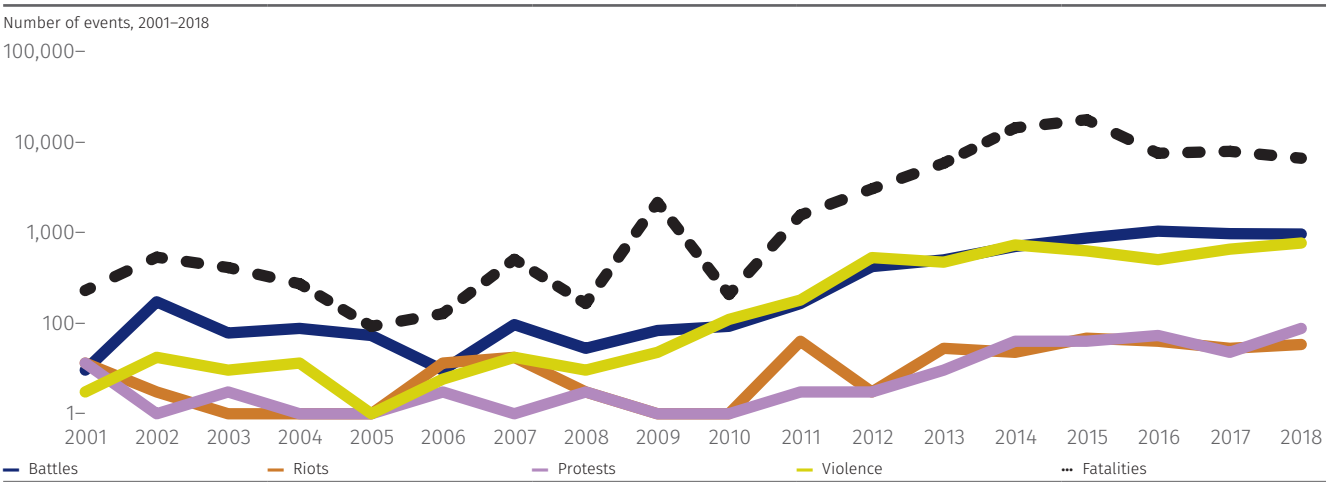
Table 6.1: Number of conflict events and fatalities 2001–2018

	Cameroon	*Chad*	*Niger*	*Nigeria*	*Total*
Conflict events	1,861	692	620	12,702	**15,875**
Battles	636	332	256	3,171	**4,395**
Protests	145	56	83	3,101	**3,385**
Riots	87	24	61	1,448	**1,620**
Violence	621	193	133	3,813	**4,760**
Fatalities	6,124	6,234	2,550	60,925	**75,833**

6.2.2 Climate

Climate and climate change are often mentioned among the most important factors for peace and development in the Lake Chad region. For instance, the lake itself has provided livelihoods for the people surrounding it for centuries, but shrank dramatically

Figure 6.1: Conflict events and fatalities over time



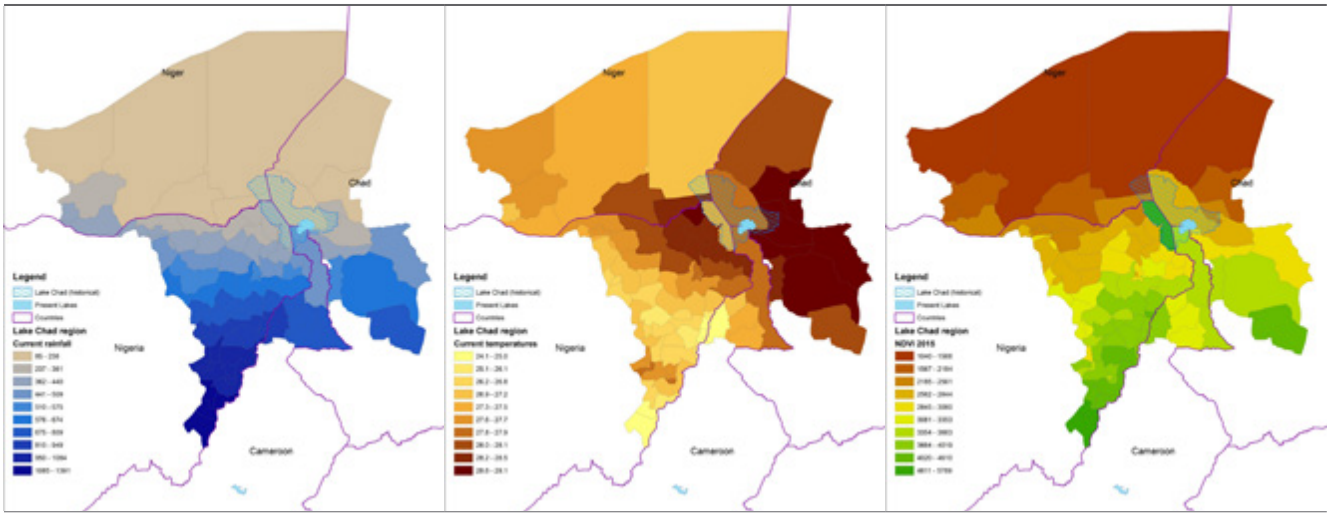
Source: Fisker 2021.

in size during the 1970's and 80's before gradually regenerating in recent decades. It now covers 56 percent of its 1973 extent, although much of the surface is now also covered by vegetation [Vivekananda et al., 2019]. Land-degradation, over-exploitation, and climate change are often mentioned as possible causes for this.

Furthermore, the region around Lake Chad is by no means uniform in terms of climate and weather. To the South, the climate is more humid, and the landscape is greener, whereas the Northern parts are drier, less green, and with a larger difference between day and night-time temperatures. The large areas that were historically submerged by the lake are still greener and cooler than other parts of the region despite relatively low levels of rainfall. Map 6.2 shows the distribution of rainfall, temperatures, and greenness across the 90 sub-national units of the region. While rainfall and greenness show a clear latitudinal gradient, temperatures are also mediated by altitude, and thus generally higher in the Eastern parts of the region.

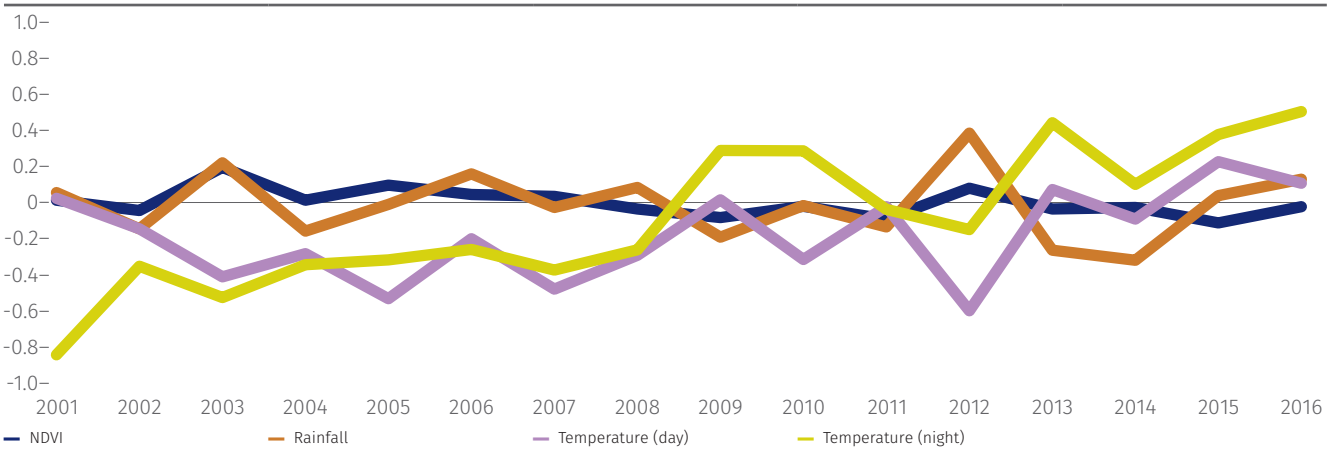
While large geographical variations exist as shown in Map 6.2, another in- teresting perspective is the variation over time. Figure 6.2 demonstrates the district-level average anomalies of NDVI, rainfall, and temperatures over the period 2001–2018. The large positive daytime temperature anomaly towards the end

Map 6.2: Average rainfall, temperatures, and NDVI



Source: Fisker 2021.

Figure 6.2: NDVI, rainfall, and temperature anomalies over time



of the period stands out while two other interesting observations is a general decline in NDVI throughout the period as well as an upward trend in temperatures. Rainfall generally fluctuates around the mean.

In this paper, drought is measured in three different ways: Firstly by anomalies in rainfall and temperatures measured respectively by the Chirps (Climate Hazards Group InfraRed Precipitation with Station) data and Modis Terra, which would correspond to the notion of meteorological droughts; secondly by NDVI anomalies—a more direct proxy for agricultural drought, and finally by the SPEI drought index which combines long time series of rainfall and temperatures to calculate the difference between precipiation and potential evapotransipiration. Despite several shortcomings, the latter is used extensively in the economics literature, for instance by Harari and Ferrara [2018].

6.2.3 Other explanatory factors

Obviously, conflict depends on other factors than the climatic: demographics, infrastructure, and economic development, to mention a few. A larger population density means more potential for disagreement and more competition for limited resources, cf Blattman and Miguel [2010]. On the other hand, a certain population number is probably needed in order for law enforcement and other societal institutions to be efficient. Likewise, infrastructure can be considered to play a roll in the spread of conflict, since an efficient road system allows armed groups to move between locations. Again, more desolate areas may also provide opportunities to hide from government forces, thus enabling local militias to form and grow. Finally, economic activity—often measured by the intensity of night lights—can affect the risk of conflict; either because richer areas contain more opportunity for looting, or because poorer areas may be easier to capture. Map 6.3 displays the distribution by district of the number of conflict fatalities during the period 2015–2019, population in 2020, and average travel time to nearest urban centre in 2015. While the distributions of the latter two indicators look similar, they measure slightly different aspects of economic development: For any given population density, travel time indicates how easy it is to move around the district.

Table 6.2 shows mean values of the different indicators split by country. In terms of average rainfall, the districts of the region belonging to Niger are the driest and Cameroon the wettest. Temperatures are highest in Chad (28.5 degrees Celsius) while the other three countries are all around one degree cooler. The largest increases in temperatures due to climate change are projected to take place in Niger, followed by Chad. Niger is also the country

Map 6.3: Conflict intensity, population density and travel time

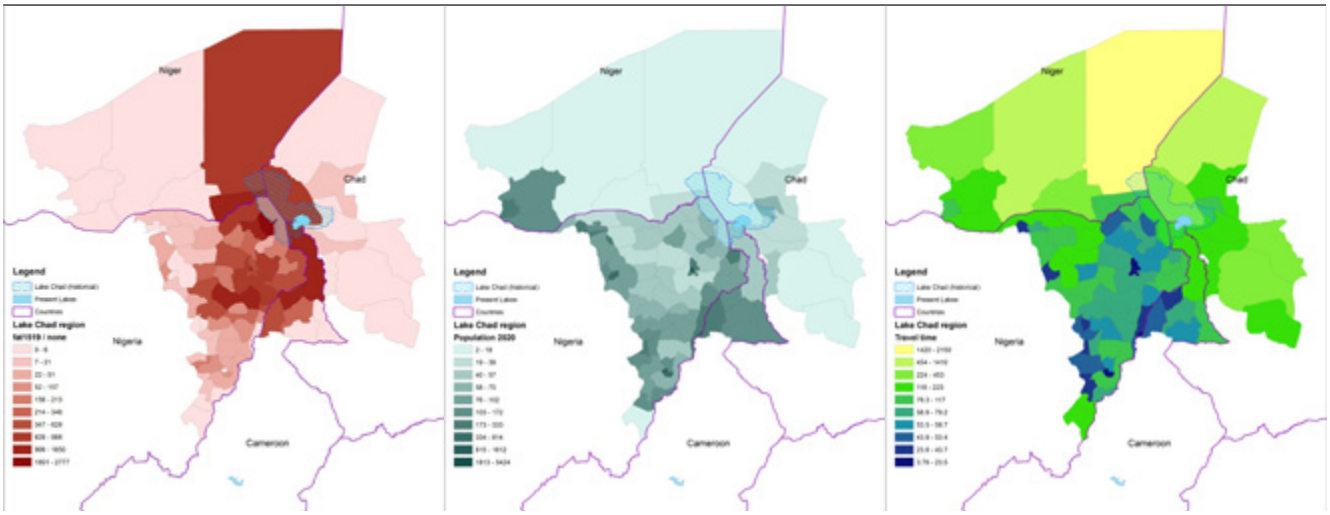


Table 6.2: Summary statistics: Mean values of climate and control variables

	Cameroon	Chad	Niger	Nigeria	Total
NDVI	0.360	0.287	0.189	0.347	0.327
Temp. (daytime)	15.42	15.51	15.48	15.40	15.42
Temp. (nighttime)	14.69	14.69	14.61	14.66	14.66
Rainfall (chirps)	61.45	36.75	24.39	63.39	56.84
Projected rainfall change	22.00	30.44	30.90	22.63	24.19
Projected temp. change	6.045	6.430	7.498	6.364	6.451
Population 2000 (1000s)	443.6	142.3	290.6	121.3	160.2
Population 2020 (1000s)	788.2	276.4	769.5	228.0	318.8
Travel time	73.27	282.1	603.4	73.19	143.5
Distance to border	25.98	96.79	97.96	72.79	74.57

with the lowest projected increase in rainfall, pointing towards even more difficult conditions for farmers and pastoralists there. NDVI values are generally much larger in Cameroon and Nigeria, and lower in Niger.

Average population numbers for districts vary between 228,000 (Nigeria) and 788,000 (Cameroon), with the districts belonging to Niger having seen the largest percentage increase between 2000 and 2020.

Travel times to urban areas are generally low in Nigeria and Cameroon, while large distances exist in Niger and to a lesser extent in Chad, the main reason being that districts in these countries stretch far into desert areas. Average distance to an international border is by far lowest in Cameroon.

6.2.4 Correlations

In order to provide an overview of how conflict incidence and intensity is correlated with the factors that form part of the analysis, Table 6.3 consists of pairwise correlations between conflict and each of the other variables when all cross-sections that form the panel are pooled.

While the effects of the climatic variables are studied in more detail in the next section, it is interesting to note here that conflict is more likely in areas with larger populations, smaller travel times to urban centres, and also in areas with a larger share of cropland areas. Regarding the latter two indicators, the correlations are reversed when observing districts compared to cells. This is likely caused by the fact that some districts are geographically large (especially in Niger and Chad) and these have lower shares of cropland area as well as larger travel distances while also less conflict.

Table 6.3: Pairwise correlations between conflict and explanatory variables in pooled data

	Any event (cells)	log(events) (districts)
Temp anom.	0.0873	0.241
Rainfall anom	0.0171	0.0345
NDVI anom	-0.0822	-0.1697
SPEI	0.0912	0.1496
log(population)	0.1409	0.5557
log(travel time)	-0.1648	0.0057
Cropland share	0.1278	-0.0598
Observations	96,642	1,692

6.3 Empirical strategy

This section lays out the approach to analysing the climatic determinants of conflict in the Lake Chad region. The analysis investigates the effects of climate on conflict from various perspectives: in the main specification, district-year conflict intensity and cell-year conflict incidence are explained by anomalies (z-scores calculated each month in the 19-year period where the value represents standard deviations from the long-term mean within the unit and month) in temperature, rainfall, and greenness as well as a 6-month SPEI drought index in a fixed effects set-up. Since both conflict and climate are spatially dynamic processes, the regressions are based upon assumptions of spatially correlated error terms, and in some specifications including a spatially lagged dependent variable. This takes into account the fact that conflict events tend to spread from a point of origin to neighboring areas.

Due to the differences in size between second-level administrative units and cells of approx. 10 km * 10 km, two different dependent variables are considered, that best exploit the variation in the data: the former case employs the logarithm of the number of conflict events (i.e. the intensity of conflict) while in the latter case, a dummy variable indicating whether a conflict event has taken place in a given cell in a given year is used (i.e. incidence of conflict).

Equation 1 describes the fixed effects model of conflict intensity/incidence and its climatic predictors at the district/cell level:

$$Conflict_{it} = \beta_1 C_{it} + \beta_2 W * conflict_{it} + \varepsilon_{it} \qquad (1)$$

where $Conflict$ is either the logarithm of the number of conflict events in a district (i) or an indicator of the presence of conflict in a cell (also i) in given year (t). C is a vector of climate anomalies observed in unit i in year t: rainfall as well as daytime temperature in the first model, NDVI (greenness) in the second, and the 6-month SPEI index in the third. In the analysis, these three models are used because they represent three different ways of measuring climatic impacts. The first model, which includes rainfall and temperature anomalies, is the most direct way of linking climate shocks to conflict intensity/incidence. The second model (with NDVI anomalies) compares the outcome of climate variations (i.e. the conditions of the vegetation) to conflict, while the third approach refers to a drought index (SPEI) that combines rainfall and temperatures into a measure that informs about agricultural potential.

$W * conflict_{it}$ is the spatial lag of the dependent variable. It measures the average number of conflict events or fatalities in neighboring districts in the same year, i.e. districts or cells that share a border with the unit in question. It does not distinguish between within-country borders and country borders in this set-up. This term is included separately as a check to whether controlling for the auto-regressive nature of conflict alters the results. ε is the random error term that allows for spatial correlation.

The climatic variables included in the baseline specification described by equation 1 are all averages for full calendar years. However, as argued by Harari and Ferrara [2018] among others, if the mechanism that links climate anomalies and conflict is economic hardship induced by agricultural drought, only the anomalies observed during the agricultural growing season should matter.

A related concern is that not all units of observation are areas of agricultural activity. If a drought-income-conflict relationship is expected, it is likely to be more directly impacting cropland areas than desert or pastoral areas. In order to capture the differential effect of climate anomalies on conflict, in equation 2, each climate variable in C is therefore interacted with the share of cropland in each unit of observation. Another potential source of heterogeneity in impacts is the population of a given

unit. More people means more potential for conflict and thus a larger effect of climate shocks could be expected. Equation 2 describes the model with heterogeneous effects, which is similar to equation 1 in all other aspects:

$$Conflict_{it} = \beta_1 C(GP)_{it} + \beta_2 C(GP)_{it} * X_i + \beta_3 W * conflict_{it} + \varepsilon_{it} \qquad (2)$$

where $C(GP)_{it}$ is a vector of climate anomalies calculated only for the growing period months i the specific locations before aggregating to years, districts and cells and X is the share of cropland in cell/district i in the year 2000.

Finally, in order to test whether the relationships depend on population density, a model is run at the cell level where conflict incidence is interacted with a dummy variable taking the value one if a cell belongs to the upper half of the population distribution.

6.4 Results

6.4.1 Baseline results

Table 6.4 includes the results of applying a fixed effects estimator to equation 1 where the units of observation are districts and the dependent variable the logarithm of conflict events in a given year. Column 1–3 contain the results of regressions where the error terms are assumed to be spatially correlated whereas column 4–6 assume spatial auto-correlation and thus include a spatially lagged dependent variable.

Each column represents a specific way of measuring impacts of climate variation: Column 1 and 4 focus on the direct relationship between weather anomalies (rainfall and temperature) and conflict intensity. Column 2 and 5 use the observed NDVI-anomalies as an observable proxy for drought conditions whereas column 3 and 6 show the effects of a common drought-index that combines long-term information on rainfall and temperatures, namely the 6-month SPEI.

The results for districts and cells are qualitatively comparable: Temperature anomalies (both daytime and night-time) show a positive effect on conflict intensity and incidence. In other words, in hotter-than-usual years, districts or cells are more likely to experience conflict activity. Furthermore, and perhaps surprisingly, positive rainfall anomalies, i.e. years where rainfall levels are above the mean are also associated with more conflict measured at both district and cells. Turning to measures of drought, NDVI anomalies have the expected sign, meaning that worse growing conditions are correlated with more conflict. The SPEI, on the other hand, shows the opposite correlation, namely that drought-years (a negative value by this measure) tend to be aligned with less widespread conflict.

Adding numbers to the results, a positive temperature anomaly of one standard deviation is associated with a 17.6 percentage points increase in the yearly number of conflict events taking place in a given district. At the cell level, a similar temperature anomaly adds 0.8 percentage points to the likelihood of a cell experiencing any conflict events in that year. A *negative* NDVI anomaly of one standard deviation leads to an increase in the number of conflict events of 8.9 percentage points at the district level whereas the likelihood of experiencing a conflict at the cell level increases by 0.7 percentage points.

Table 6.4: Baseline results, Districts

	(1)	(2)	(3)	(4)	(5)	(6)
Temp.	0.176*** (0.028)			0.099*** 0.015)		
Rainfall	0.011 (0.027)			0.013 (0.014)		
NDVI		-0.089*** (0.028)			-0.057*** (0.014)	
SPEI			0.165*** (0.048)			0.080*** (0.022)
Spat. lag Conf. events				0.784*** (0.020)	0.796*** (0.020)	0.811*** (0.019)
N	1,692	1,598	1,692	1,692	1,598	1,692
Pseudo-r2	0.059	0.029	0.022	0.067	0.037	0.028

Note: Spatially correlated standard errors in parentheses. Fixed effects. Z-scores. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 6.5: Baseline results, Cells

	(1)	(2)	(3)	(4)	(5)	(6)
Temp.	0.008*** (0.001)			0.006*** (0.000)		
Rainfall	0.002*** (0.001)			0.001*** (0.000)		
NDVI		-0.007*** (0.001)			-0.005*** (0.000)	
SPEI			0.011*** (0.001)			0.006*** (0.001)
Sp_lag				0.443*** (0.005)	0.446*** (0.005)	0.450*** (0.005)
N	91,273	91,273	91,273	91,273	91,273	91,273
psudo-r2	0.01	0.01	0.01	0.01	0.01	0.01

Note: Spatially correlated standard errors in parentheses. Fixed effects. Z-scores. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

All results are robust to controlling for the geographical spillover of conflicts. Column 4–6 of Table 6.4 and 6.5 add a spatially lagged version of the dependent variable that measures the average conflict incidence or number of conflict events in neighboring units (i.e. districts or cells that share a border with the district or cell in question). This variable generally has a large contribution to explaining conflict intensity while point estimates on the explanatory variables tend to drop slightly.

Table A6.2 and A6.3 in the appendix show results of estimating a model including temporal lags of the explanatory variables. It is demonstrated that temperature anomalies are significant predictors of the number of conflict events at the district level up to three years into the future. NDVI anomalies, on the other hand, only predict conflict with statistical significance in the same year as the conflicts. This fits well with the notion of NDVI anomalies being a more direct proxy of vegetation conditions on the ground than other climatic variables.

6.4.2 Exploring heterogeneous effects

A central question that remains to be addressed is whether the results found in table 6.4 and 6.5 are caused by a drought-income-channel where conflict is more likely in places where farmers are suffering from economic hardship. In order to investigate that, the next set of results will include climate anomalies calculated on basis of growing season months only, and further introduce interaction terms between each variable and the share of cropland within a unit of observation. This largely follows the approach of Harari and Ferrara [2018] who found an effect growing season SPEI on conflict incidence across all of Sub-Saharan Africa, albeit with much larger units of observations.

Table 6.6 and 6.7 show the effects of growing season-specific climate anomalies on conflict in districts and cells respectively. Both tables further include interactions between these and the share of cropland within each unit.

Temperature anomalies are still positively associated with conflict; especially in areas with more cropland.

For drought measured by NDVI anomalies, the negative effect observed in the baseline model also persists. Additionally it should be noted that the effect is weaker in areas of no cropland and larger, the larger the share of a unit is considered cropland. This is in line with expectations that bad harvests can lead to more conflict through an income channel.

Turning to rainfall and SPEI—the two variables where results opposite to the expectations were found in the baseline analysis, a few interesting observations are

Table 6.6: Heterogeneous effects, Districts

	(1)	(2)	(3)
GP Temp. anom.	0.021 (0.047)		
GP Rainfall anom.	0.002 (0.043)		
Cropland*GP Temp. anom.	0.478*** (0.112)		
GP NDVI anom.		-0.086* (0.051)	
Cropland*GP NDVI anom.		-0.219* (0.117)	
GP SPEI			-0.173** (0.070)
Cropland*GP SPEI			0.464*** (0.159)
N	1,692	1,692	1,692
pseudo-r2	0.07	0.05	0.01

Note: Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 6.7: Heterogeneous croplands effects, Cells

	(1)	(2)	(3)
GP Temp. anom.	0.002* (0.001)		
GP Rainfall anom.	0.001 (0.001)		
Cropland*GP Temp. anom.	0.046*** (0.001)		
Cropland*GP Rainfall anom.	0.004 (0.003)		
GP NDVI anom.		-0.001 (0.001)	
Cropland*GP NDVI anom.		-0.036*** (0.003)	
GP SPEI			0.001 (0.002)
Cropland*GP SPEI			0.025*** (0.004)
N	61,013	61,013	61,013
pseudo-r2	0.02	0.01	0.00

Note: Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

noted: Firstly, the positive correlation between rainfall and conflict disappears when only considering the growing seasons. The same is true for SPEI, however, when focusing on the agricultural areas, the positive (and somewhat contradictory) relationship re-emerges.

Another potential mediating factor is population density. In Table 6.8, *Urban* refers to a situation where the population of a cell is larger than the median of the distribution, which serves as a crude way of distinguishing between urban and rural areas. What is evident is that the effects of climate anomalies on conflict events are largely driven by areas witha population density above the median. In all cases the point estimates retain their direction, but become much more significant (statistically and economically) when adding the urban interaction terms.

Results including heterogeneous effects related to market access (travel time to nearest urban area) are not included as they are similar to those where population is used as interaction term.

Table 6.8: Heterogeneous population effects, Cells

	(1)	(2)	(3)
Temp. anom.	0.002*** (0.001)		
Rainfall anom.	0.000 (0.001)		
Temp. anom. (day)*Urban	1.288*** (0.095)		
Rainfall anom*Urban	0.385*** (0.095)		
NDVI anom.		-0.002*** (0.001)	
NDVI anom*Urban		-1.251*** (0.093)	
SPEI			0.003** (0.001)
SPEI*Urban			1.404*** (0.165)
N	91,273	91,273	91,273
pseudo-r2	0.01	0.01	0.00

Note: Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

6.5 Conclusion

In conclusion, this study finds that the distribution of conflict events across time and space in the Lake Chad region is correlated with climatic factors.

Higher-than-usual temperatures leads to an increase in conflict activity both measured at the district level and the more detailed grid cell level. The same is true for observed greenness anomalies, an effect that becomes stronger when focusing on anomalies during the growing season in cropland areas. However, rainfall (CHIRPS) and SPEI are not showing similar relationships with conflict. Two possible explanations for these apparently contradictory findings stand out: The first possibility is that conflict in the Lake Chad region is, in fact, affected much more by temperature anomalies than rainfall anomalies. This would be in line with the hypothesis that there the channel through which the relationship operates is more physiological than depending on agricultural income. A second possible explanation for the seemingly opposite results could simply be measurement errors in the SPEI and CHIRPS data sets. Both of these data sources are (partly) interpolated from weather station observations, and the distance to the nearest weather station is sometimes large. Figure A.1 in the appendix shows the distribution of weather stations used by CHIRPS and CRU (the database behind SPEI) respectively in the Lake Chad Region. There are around 12 (CHIRPS in 2010) and 7 (CRU in all years 2000-2014) weather stations in the region with observations that feed into the Chirps and SPEI data sets. This compares to 90 districts and 5,369 cells. So for a large majority of the observations in this analysis, rainfall and the SPEI will be based entirely on interpolations. On the contrary, the spatial resolution of NDVI and Temperatures is higher than the cells used, so in that case, the observed values are more valid. Likewise, conflict data is aggregated from high precision geographical coordinates, so there is also high confidence that the conflicts actually took place in the recorded locations.

Based on this it is therefore not possible to conclude which of the explanations is more likely. The fact that NDVI anomalies show expected signs and the effect is more pronounced in croplands during growing season points toward the measurement error explanation. However, this relation could to some extent also be spuriously driven by temperatures affecting both NDVI and conflict. More precise rainfall data, for instance from the Global Precipitation Measurement Mission (GPM) might shed more light on this puzzle.

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Appendix

Table A6.1: Data sources

	Indicators	*Data format*	*Spatial resolution*	*Temporal coverage*	*Source*
Population	Number of people per cell	Raster (tiff)	30 arc seconds (~1 km)	2000, 2020	World Pop
Infrastructure	Intensity of Night-time lights (average radiance)	Raster (tiff)	500 m pixels	Monthly - here April 2012 (earliest available) and April 2019	Visible Infrared Imaging Radiometer Suite (VIIRS)
	Accessibility to cities (travel time to nearest urban center)	Raster (tiff)	1 km	2015 (update and improvement to 2000 dataset)	Malaria Atlas Project
Climate	Precipitation	Raster (tiff)	2.5 arc minutes (~4 km)	Monthly, 2000–2018	Chirps
	Greenness (NDV) and temperature	Raster (HDF)	0.05 degrees (~5 km)	Monthly, 2000–2018	Modis Terra, mod13c2
Climate Change	Projected temperature and precipitation (CMIP6, SSP2.5)	Raster (tiff)	2.5 arc minute (~4 km)	2014–2060	Worldclim
Conflict	Number of events + Fatalities (Battles, protests, riots, violence against civilians)	Geo-referenced event (point) data	GPS points aggregated to district level	2015–2019 and change between 1014 and 1519	ACLED

Table A6.2: Baseline results with time lags, district level

	(1)
Temp. anom. (day)	0.192*** (0.034)
L.Temp. anom. (day)	0.132*** (0.031)
L2.Temp. anom. (day)	0.201*** (0.047)
L3.Temp. anom. (day)	0.065* (0.038)
Rainfall anom.	-0.022 (0.026)
L.Rainfall anom.	-0.080*** (0.027)
L2.Rainfall anom.	-0.018 (0.026)
L3.Rainfall anom.	-0.086*** (0.030)
Constant	0.769*** (0.028)
N	1410
r2	0.17

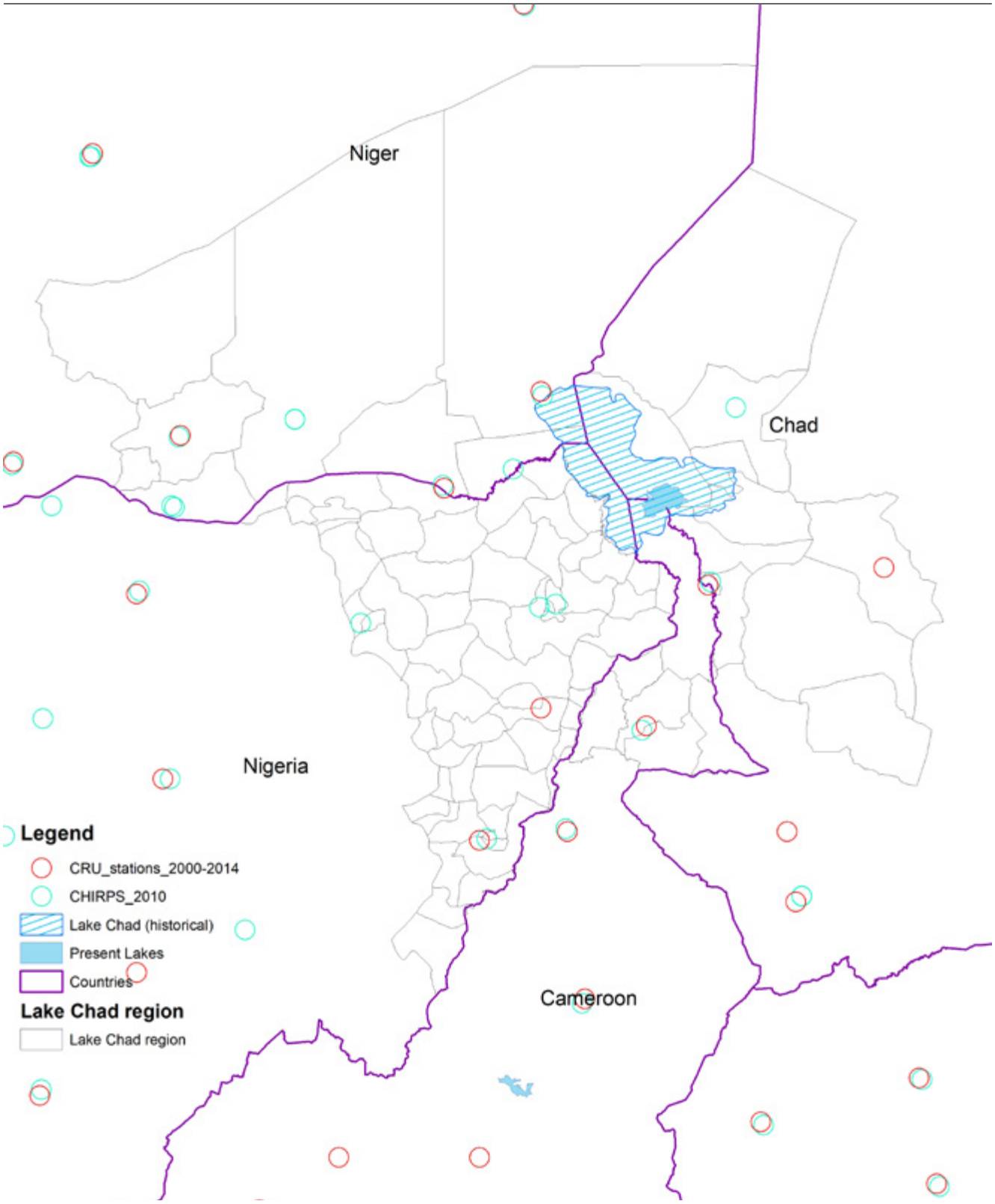
Note: Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table A6.3: Baseline results with time lags, district level

	(1)	*(2)*
NDVI anom.	-0.168*** (0.025)	
L.NDVI anom.	-0.055 (0.067)	
L2.NDVI anom.	-0.058 (0.048)	
L3.NDVI anom.	-0.118 (0.076)	
(mean) spei06		0.321*** (0.043)
L.(mean) spei06		0.206*** (0.034)
L2.(mean) spei06		0.206*** (0.030)
L3.(mean) spei06		0.110** (0.045)
Constant	0.673*** (0.032)	0.942*** (0.044)
N	1,316	1,410
r2	0.06	0.11

Note: Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Figure A6.1: Distribution of weather stations in the Lake Chad region



Technical Paper 6. Building Rural Development in the Lake Chad Region

Brian Blankespoor (World Bank)

7.1 Introduction

Limited market accessibility, and more recently conflict, hinder agricultural production and therefore pose major challenges to the economic recovery and development of the Lake Chad region. More than 250 million people live in the four countries of the Lake Chad region, where the vast majority of the people depend on agricultural activities for their livelihoods. Compounding limited paved roads in agricultural areas is the occurrence of numerous violent events from the decade long insurgence of Boko Haram near Lake Chad. Displaced and conflict-affected households face limited market access and economic opportunities to earn income (FEWS NET, 2021). Therefore, it is very timely and crucial to understand the links between these challenges and agricultural activities.

The objective of this paper is to gain insight on the current state of rural development in the Lake Chad countries by examining the relation between road investments and cropland expansion over the past three decades following the framework in Berg et al. (2018) and then by investigating rural development in proximity to conflict events arisen by the insurgence of Boko Haram this past decade.

Over the past several years, roads have improved in the Lake Chad region (Magrin et al., 2018), yet limited paved roads and road maintenance continues to be a challenge. Nigeria has one of the largest road networks in West Africa in terms of length of roads. However, the percentage of national roads in a bad state increased from 23 percent in 1985 to 60 percent in 2010 (Federal Government of Nigeria, 2010). The other three countries have less paved roads. The concentration of roads in Niger is mainly in the south along the West-East route of Niamey to Nguime via Diffa as well as the a triangle including Agadez, Tahoua and Zinder. Chad has limited paved roads, which are mainly concentrated in the capital region. The roads in Cameroon connect the main port of Douala and the administrative cities including the capital Yaoundé. Unpaved roads continue to pose challenges during the rainy season.

Connectivity is very important to the local economy and cross-border trade. Previous literature demonstrates that road infrastructure is conducive to regional trade and growth where it can facilitate local economic growth with the reduction in input and transportation costs, while connecting the potential for higher prices of crops (Crawford et al., 2003; Redding and Turner, 2015; Berg et al., 2017; Aggarwal, 2018; Henderson et al., 2017; Jedwab and Storeygard, 2020; Storeygard, 2016; Jedwab and Storeygard, 2019). In Nigeria, roads can facilitate growth of the non-agricultural sector (Ali et al., 2015) and improve access to market that has been linked to the adoption of modern technologies (Damania et al., 2017). Even so, Chamberlin et al. (2014) show that suit able land remains uncultivated in Sub-Saharan Africa due to limited transport access. Using panel methods over which significant road development took place from 1970 to 2010 in Sub-Saharan Africa, Berg et al. (2018) demonstrate a modest impact of improved market access on cropland expansion and suggestive evidence of impacts on the local intensity of croplands.

Not only are roads crucial to the Lake Chad region, but these countries are also linked to the water resources of Lake Chad, which is a large area natural transboundary resource that supports local livelihoods including farming, livestock, and fisheries (Déby Itno et al., 2015). Due to environmental changes and human activities, Lake Chad has shrunk approximately 90 percent from 1960 levels, when it was the world's sixth largest inland water body. The region is subject to droughts as well as human activities have altered the hydrology of this endorheic lake by stream flow modification and water diversion (Lemoalle et al., 2012), which contributes to the water scarcity and fragility of the region (Okpara et al., 2015). Droughts can challenge agricultural production and correspond to an increase in violence

against civilians (Bagozzi et al. 2017). In addition to the administrative challenges of a transboundary resource, the fluctuations in interannual and seasonal water impede the development of stable resources exploitation rights (Sarch, 2001) and reduce groundwater discharge along with loss in biodiversity (Odada et al., 2003).

Along with the environmental changes over the past few decades, the fragility of the region has increased in the past decade due to the insurgency from Boko Haram in northern Nigeria that contributes to humanitarian challenges in the region. Conflict can drive population displacement, impede the normal activity of local markets, and constrain household access to livelihood, food and income. Conflict events from Boko Haram started in 2009 have caused massive displacement of people and disruption to the agricultural sector including market activities (Awodola and Oboshi, 2015; Van Den Hoek, 2017; Jelilov et al., 2018). The conflict has displaced a large number of individuals who have experienced significant income shocks with an increase of over 40 percent chance of having no income based on an analysis of Nigeria (UNHCR and World Bank, 2016). From a recent report by OCHA (2020), the Lake Chad region has 2.6 million Internally Displaced People with 256 thousand refugees, and 5.2 million people are severely food insecure as of 16 September 2020. FAO (2017) recently reported that nearly 50 percent of the 704,000 people in Niger are in dire need of humanitarian assistance and nearly 20 percent are facing issues of food security. For Nigeria, nearly 70 percent of the 12 million people are in need of humanitarian assistance with 43 percent facing issues of food insecurity. Employing a Difference in Differences framework with panel household survey data, Agwu (2020) finds that exposure of households to conflict events from Boko Haram is associated with significant downward movements in food security. In a study of Africa, Maystadt et al. (2020) find evidence of agricultural expansion near refugee-hosting areas, whereas Salemi (2021) finds evidence of small increases of forest loss (intensive margin and not extensive margin) in areas near refugee camps in Sub Saharan Africa.

Although an explicit strategy by Boko Haram to attack markets is not known, markets are still a key location to disrupt trade and target civilians. Using conflict event data Van Den Hoek (2017) reports 38 direct attacks on markets in Borno state, Nigeria, between November 2014 and December 2016, which is nearly two market attacks per month. The paper also finds seasonality in the timing of the attacks, which occur prior to the lean season and just after the harvest. Both of these periods have the potential to disrupt agricultural production and trade by various channels: impeding physical access, access to inputs, the timing of planting and harvesting, and abandoning of fields. Adelaja and George (2019) examine the effect of the Boko Haram conflict on agricultural productivity using a nationally representative panel dataset and micro data from the ACLED database.[358] They do not find a decrease in the total hectares of agricultural land harvested, however they do find a significant reduction in total output and productivity from the Boko Haram attacks. Adebisi et al. (2016) find negative impact on agribusiness in Borno state, Nigeria. Barra et al. (mimeo) examine the relationship between conflict and poverty in Nigeria considering the connectivity where they find that decreasing transportation costs with less multidimensional poverty. Ali et al. (2015) find that reducing transportation costs in Nigeria increase measures of welfare.

This paper examines the relationship between access to markets and land cultivation following Berg et al. (2018) using panel methods. Then, I contextualize these results within the broader recent development challenges of the Lake Chad region. The results provide evidence that an increase in market access is associated with an increase in cultivated land and is positively associated with an increase in local agricultural GDP. Even so, conflict from the rise of Boko Haram in the past decade can attenuate gains whereby the proximity to conflict events in the previous year is associated with less cropland across the entire region and less night time lights from over a hundred local markets nearby Lake Chad.

358 They use the Living Standard Measurement Study Integrated Study on Agriculture dataset with three waves: 2010–11, 2012–13 and 2015–16.

This paper makes two contributions. First, the importance of market access as part of economic development is well known, yet advancements in measurement of agricultural activity derived from satellite data and recent data are necessary to gain current insight given developments in the region. Following Berg et al. (2018) who examine Sub-Saharan Africa during the period 1970 to 2010, I examine market access for rural development in the Lake Chad countries over a period during which changes in cultivated area and modest road improvements took place. I provide contemporary insights with a higher spatial resolution measure of cropland derived from satellite data at 300m from 1992 to 2019 building on the findings in Berg et al. (2018).[359] In addition, I use a newly available data set on agricultural GDP (Blankespoor et al., forthcomingc) to examine the impact of market access on local agricultural GDP.[360] Similarly, I examine the local conditions in each grid cell to determine if areas of increased cultivated land are exposed to more suitable agricultural production conditions. I focus on the extensive margin of cropland expansion (rather than intensification) given the strong dependence on rainfed agriculture and the relatively small share of cropland that is classified as irrigated.

Second, this paper contextualizes the findings of market access with local conditions given the numerous conflict events in the past decade from Boko Haram. First, I examine the impact of proximity of conflict events on cropland expansion during the period 2009 to 2019 for the entire region. Second, I build on the market level analysis by Van DenHoek (2017) who examines agricultural market activity for 104 markets nearby Lake Chad. I examine the impact of conflict by adding more recent observations of market status in a new framework that includes local night time lights as a proxy for local economic activity and a measure of proximity to Boko Haram events.

The rest of this paper is structured as follows. Section 2 describes the data sources while section 3 presents the empirical framework, section 4 presents the results, and section 5 concludes.

359 Before 2000, the HYDE 3.2 database methodology uses a weighting algorithm to estimate cropland including slope where as the measure from ESA is the result of supervised and unsupervised methods using satellite time-series data.

360 Berg et al. (2018) examine the impact of market access on total GDP; they did not examine the impact on the agricultural sector.

7.2 Data and Sample

Given the challenges of data collection across multiple countries, geospatial methods integrate a variety of data at a consistent unit of 0.1 × 0.1 degrees (approximately 11km × 11km at the equator) covering the four countries surrounding the Lake Chad. I intersect these grids with the national border to create a total of 33,252 pixels along with the corresponding area. The number of observations depends on the locations and time-step included in the regression. The regional analyses with full geographic coverage includes all pixels times the number of years. The geographic definition of the Lake Chad area is from the World Bank Lake Chad Regional Recovery and Development (PROLAC) project.[361] The local market level analysis is limited to the pixels with field based observations of a 104 markets summarized at the pixel level by season. These datasets provide insight into agricultural activity given the limited official statistics and access to the field. Below is a description of the datasets.

7.2.1 Local conditions

Agricultural production is subject to the local variation in annual climate and initial conditions (Zaveri et al., 2020). Figure 1 illustrates the shared boundary of Lake Chad as well as major transboundary rivers including the Niger and Benue from the Global Lakes and Wetlands Database (Lehner and Döll, 2004). Lake Chad has extensive floodplains and wetlands (Odada et al., 2005).

I summarize mean annual precipitation and its square at the cell-year level from the CHIRPS dataset version 2 (Funk et al., 2015). FAO (2013) provides a measure of agricultural suitability based on soil and climate conditions for twelve major crops for the period 1981–2010 from the ClimAfrica project (WP4).[362] Another measure is a common drought index with the Standardized Precipitation Evapotranspiration Index (SPEI) algorithm (Beguería et al., 2014) using the monthly precipitation and evapotranspiration 1950–2019 data version 4 from the Climate Research Unit (Harris et al., 2020). I count the number of months in a cell that are considered severe drought with values below or equal to -1.5 (Guenang and Kamga, 2014). Given the time scale over which water deficits accumulate for agricultural is important and I run the 18 month lag.[363]

7.2.2 Land cover and agricultural activity

Land cover estimates from satellite data provide a geographically comprehensive and consistent measurement from which to identify trends in agricultural activity (Weiss et al., 2020). Previous work by Berg et al. (2018) examined cultivated area from 1970 to 2010 using cropland estimates in the History Database of the Global Environment (HYDE) 3.2 (Klein Goldewijk et al., 2017). A more recently released dataset is from the European Space Agency (2017, 2019) that provides annual estimates of land cover at 300m from 1992–2019 which are harmonized from two data products Land Cover Maps - v2.0.7 and Land Cover Maps - v2.1.1.[364] I aggregate the 38 categories into six: irrigated and rainfed cropland, cropland mosaic, grassland, urban, bare land and other.[365] I summarize these data by pixel into the share of cropland per pixel.[366] I also include another measure of

361 It includes the following administrative areas: Far North Region (Cameroon); Lac, Kanem, Hadjer Lamis, and Chari Baguirmi Regions (Chad); Diffa and Zinder Regions (Niger); and Borno, Adamawa and Yobe States (Nigeria). Notably, the definition excludes N'Djamena in Chad.

362 FAO GAEZ version 4 was unavailable at the time of analysis to measure high agricultural suitability following (Berg et al., 2018).

363 The 18 month SPEI provides information of precipitation patterns over a medium to long time scale.

364 Liu et al. (2018) examine the correlation between cropland area in FAOSTAT and ESA-CCI-LC.

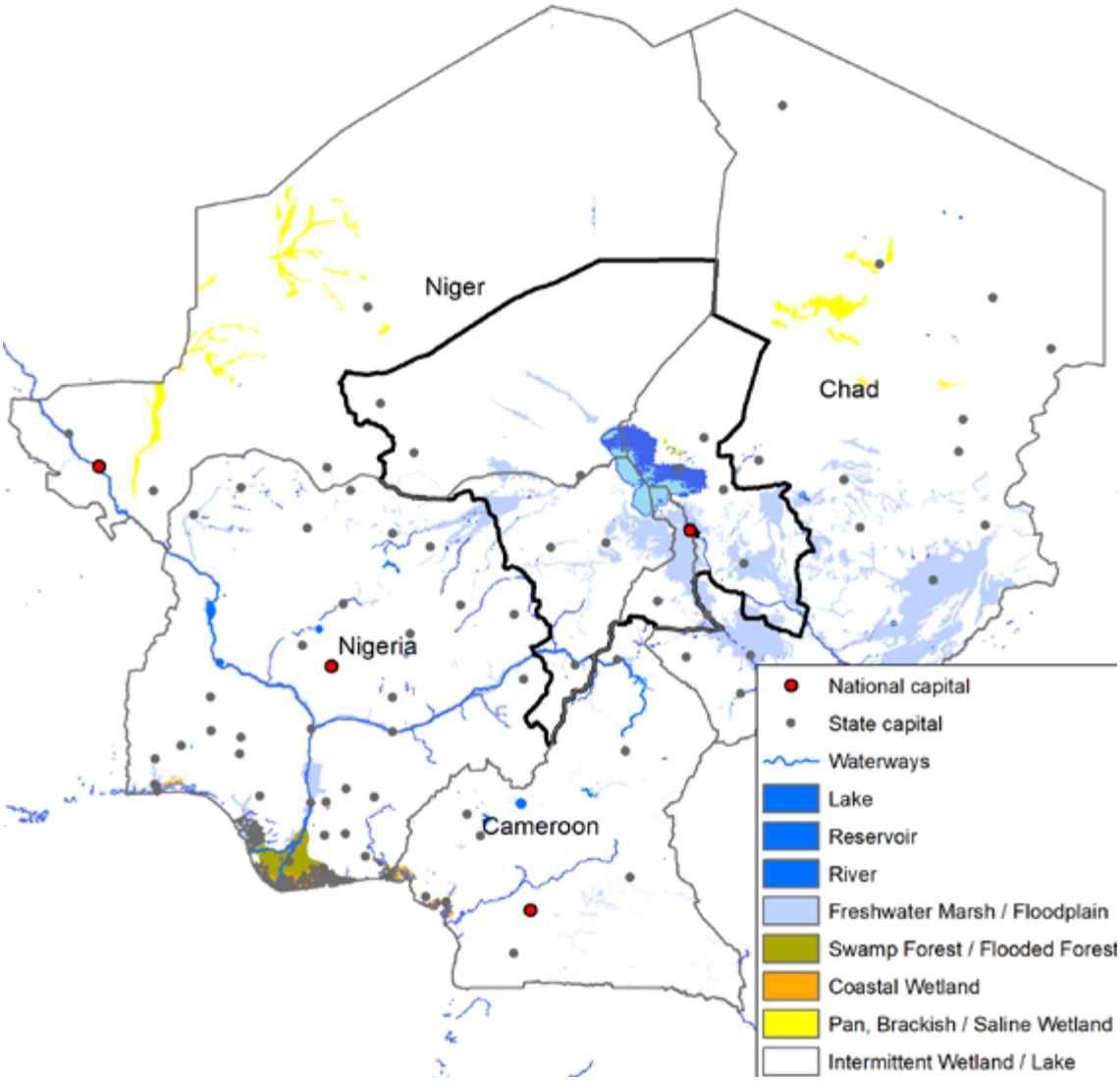
365 Specifically, I aggregate the landcover classes 10–12 into cropland; 20 as irrigated, 30 as mosaic cropland; 150 as grassland, 190 as urban and the remaining codes defined as other.

366 The area considered irrigated is significantly smaller than cropland.

cropland that includes more than 50 percent mosaic crop lands with less than 50 percent natural vegetation (tree, shrub, herbaceous cover) to include mixed land use with smallholder agriculture.

The land cover model provides an estimate of annual agricultural land use, however it aggregates any seasonal variation. So, following Blankespoor et al. (forthcomingb) and a calendar with the seasons of major crops for each country from FAO (2020a,b,c,d) I define each month into three seasons: (i) land preparation; (ii) sowing and growing; and (iii) harvest. I summarize the measures below at the season level. Another measure to gain insight on agricultural activity is from a measure of burned areas derived from satellite. Burning agricultural fields is a common practice in Central and West Africa and can reduce post-harvest fires as well as provide short-term nutrients (Bucini and Lambin, 2002; Kull and Laris, 2009). I summarize the area from the MODIS Burned Area data product (v6) in a cell, which provides a burned-area estimate per 500m pixel by month (NASA, 2020a). The intensity of land use is measured from a greenness measurement called Normalized Difference Vegetation Index (NASA, 2020b). Another measure of vegetation

Map 7.1: This map illustrates the distribution and type of waterbodies from Lehner and Döll (2004) and the Lake Chad area within the solid black line



growth is Net Primary Productivity that captures the solar energy absorbed by plants or other primary producers (Running et al., 2004). Previous work shows a strong positive correlation between these estimates and crop yields (e.g. Strobl and Strobl, 2011; Zaveri et al., 2018). The source is from the MODIS satellite product (MOD17A2H) as summarized by monthly mean of a cumulative 8-day composite with a 500m resolution (NASA, 2020c). Cross-sectional spatial distribution of crops such as cotton are from the Spatial Production Allocation Model (SPAM) (Yu et al., 2020).

In addition to cropland, the livestock and fishing trade are important activities in the Lake Chad region, especially near Lake Chad. The spatial distribution of livestock ca. 2010 is from Gilbert et al. (2018). They provide estimates livestock including cattle and goat based on agricultural census data with equal weights.[367] Lake Chad was once one of the great fisheries. Graaf et al. (2014) in FAO (2017) estimate of fishing activities in the region at a value of USD 54 to 220 million. However, current indiscriminate fishing practices are not sustainable, yet employed as a coping strategy for survival (Eriegha et al., 2019).

7.2.3 Market Access

Following Jedwab and Storeygard (2019) and Berg et al. (2018), I calculate the local market access for a given location as a function of the weighted sum of the populations of all other locations, with a weight that decreases with travel time. Formally, I define market access in a location i at time t:

$$M A_{i,t} = \sum_{j \neq i} P_{j,t} \, \tau_{i,j}^{-\sigma} \qquad (1)$$

where $P_{j,t}$ is the population in location j at time t, $\tau_{i,j}$ is the travel time between locations i and j at time t, and σ is a trade elasticity parameter. Market access depends on the road types and topography between locations i and j at time t through the values $\tau_{i,j}^{-\sigma}$ and excluding itself and cells within 20km. Following previous studies (Berg et al., 2018; Jedwab and Storeygard, 2020), I use the value for the elasticity of trade σ equal to 3.8 from Donaldson (2018) who derived it for the case of India. The travel time is calculated based on a time cost raster method using the Dijkstra algorithm as the minimum time result from the roads and offroad speeds. For the years 1983, 1992, 2001 and 2010, I assign a speed based on road categories similar to Berg et al. (2018); Jedwab and Storeygard (2020)[368] and offroad speed based on the hiking function from (Tobler, 1993).

$$Hiking = 6 * e^{-3.5*|s+0.05|} * 0.6$$

where s is mean slope from Verdin et al. (2007).

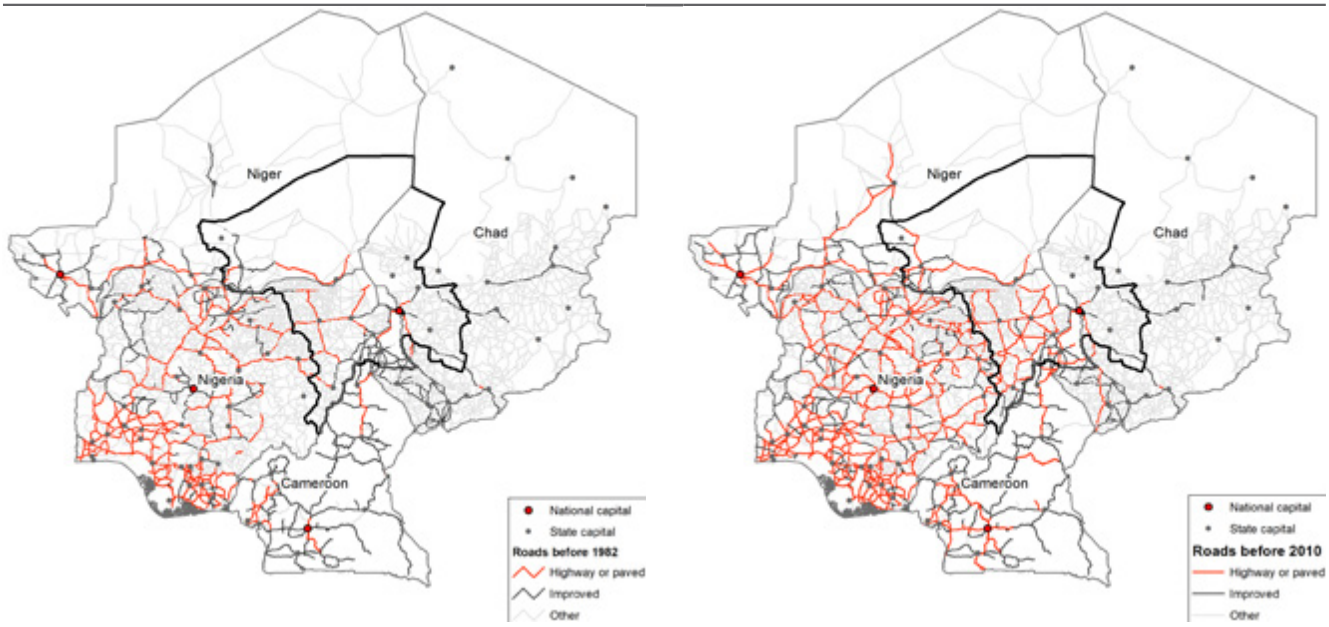
For panel roads, I use the georeferenced panel roads data from 1983 to 2010 from (Jedwab and Storeygard, 2019). The length of paved roads increased in Chad along with Cameroon, while Niger and Nigeria does not increase significantly (See Map 7.2).

The size of the market is based on urban population data from the consolidated urban population database (Blankespoor et al., 2017). The population has increased over the past decades. The distribution of population in the Lake Chad area has high variation, where Nigeria has much higher population than the other three countries.

The regional analysis also considers other important infrastructure and markets. Ports provide an important connection to the international market. The location of marine ports is from the World Ports Index (National Geospatial-Intelligence Agency, 2014). The busiest marine port in Cameroon is Douala followed by Limbé. Nigeria has major ports including: Lagos, Calabar, Onne, Port Harcourt and Warri. I construct a variable estimating the minimum travel time to a port. The locations of

367 They also provide a version as the result of statistical models with dasymetric weighting.
368 Specifically, highway speed is 80kph; paved is 60kph; improved is 40kph and earthen is 12kph.

Map 7.2: Map illustrating highway (red), paved (black) and improved (pink) roads from (Jedwab and Storeygard, 2020)



cotton ginning factories are digitized from a map on *Cotton Zones, Ginning Factories and Exports of West Africa* in OECD (2006). The locations of regional livestock markets are from FEWS NET (2009) for Chad and Niger FEWS NET (2008) for Nigeria and from Motta et al. (2019) for Cameroon. Within the Lake Chad region, the trade routes depend on connectivity of infrastructure across borders, especially Chadian livestock along with the collection of Cameroonian livestock on the way to Nigeria (Magrin et al., 2018).

For local markets near Lake Chad, the Famine Early Warning Systems Network (FEWS NET) reports provide both time and place of the operational status, which are based on field-based investigations, into four qualitative categories: (i) normal activity/operating normally (ii) some disruption, reduced activity/operating slightly below normal, (iii) significant disruption, limited activity/operating well below normal or (iv) minimal or no activity/not operating. Following Van Den Hoek (2017) I use the closed and normal operational status and then I aggregate the well below normal status and below status into a combined below normal category for a total of three categories. They produced this report every few months starting with the earliest publicly available market activity report in January 2015, which focused on market activities in December 2014. I summarize the most restrictive category during the season and I exclude 32 missing observations during the six year period of record (N = 104 * 3 * 6 - 32 = 1840); including a one year lagged variable reduces the number of observations equal to 1533.

7.2.4 Economic activity

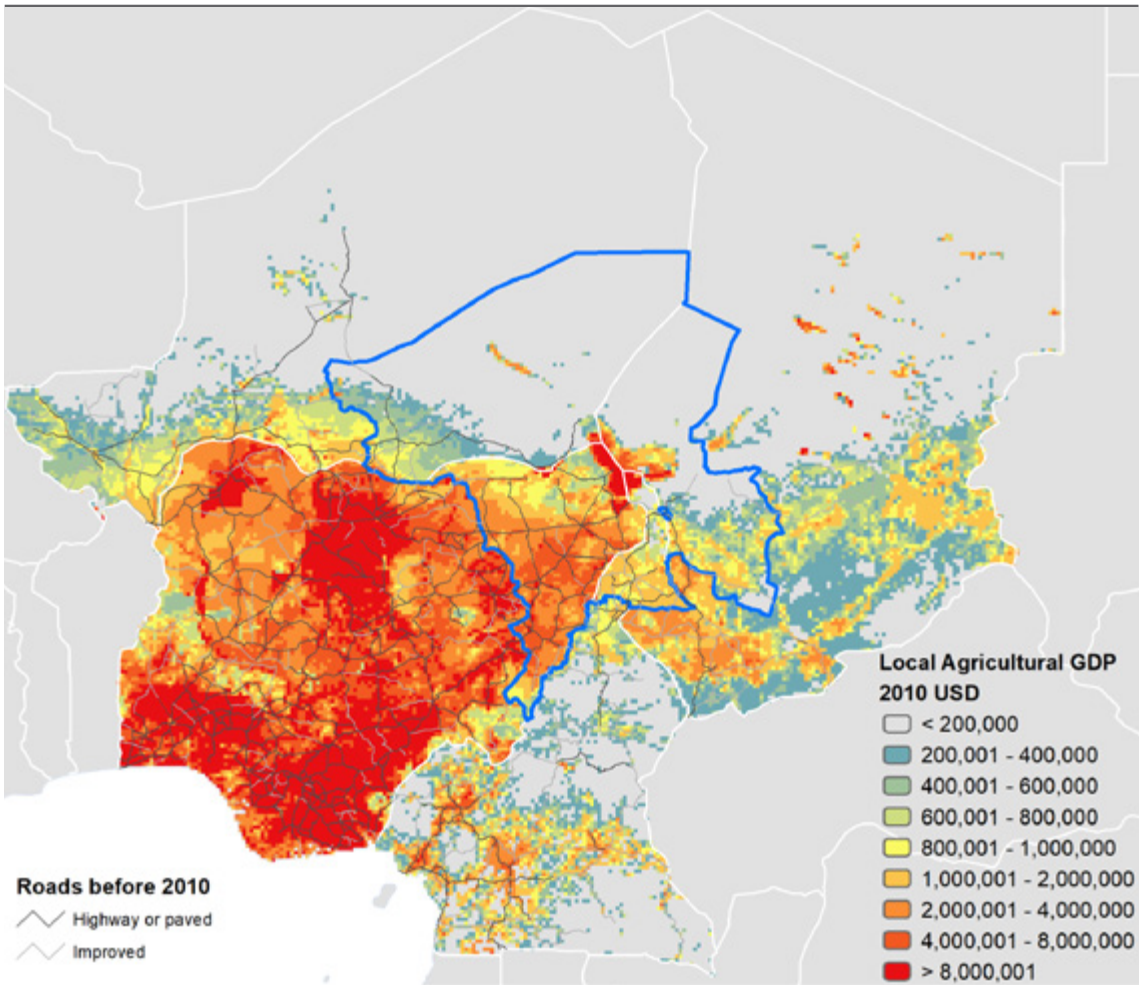
Night time lights can proxy total local economic activity (Henderson et al., 2011) **and human development** (Bruederle and Hodler, 2018). I use two night time lights datasets due to the time-step. For annual trends across the region from 1992–2018, I use the dataset that harmonizes two data sources DMSP-OLS and VIIRS data from Li et al. (2020).[369] The second source is the monthly data from VIIRS available from April 2012 until 2020.[370]

369 DMSP-OLS (1992–2013) is used for temporal calibration with a simulation of VIIRS data (2014–2018). These satellites measure light at night at different times of day.

370 I calculate these values using the Stray Light Corrected Nighttime Day/Night Band Composites Version 1 product.

After visual inspection and inline with previous work by Li et al. (2020), I calculate the sum of the radiance values above 0.3 by pixel.[371] Even with the striking correlation of night time lights and total GDP, these measures require areas to emit light at night to relate to economic activity, which is not prevalent in many rural areas (Thomas et al., 2019). So, it does not account well for a significant contribution to the economy from the agricultural sector. Over the past two decades, Chad, Niger and Nigeria have a higher share of agricultural GDP than the Sub-Saharan Africa regional aggregate.[372] To fill this local data gap, (Blankespoor et al., forthcomingc) employ a data fusion method based on cross-entropy optimization that disaggregates administrative level agricultural GDP into grids depending on satellite-derived indicators of the components that make up agricultural GDP, namely crop, livestock, fishery, hunting and timber production. Map 7.3 illustrates the distribution of agricultural GDP circa 2010. The cropland component takes advantage of the SPAM model to inform the prior allocation of cropland production value and does not directly use infrastructure data (Yu et al., 2020). The level of agricultural GDP in Nigeria is considerably higher compared to Cameroon, Chad and Niger.

Map 7.3: This map illustrates main roads along with the distribution of Agricultural GDP (2010) from (Blankespoor et al., forthcomingc), where darker red represents relatively higher agricultural GDP and light blue or transparent has little estimated value



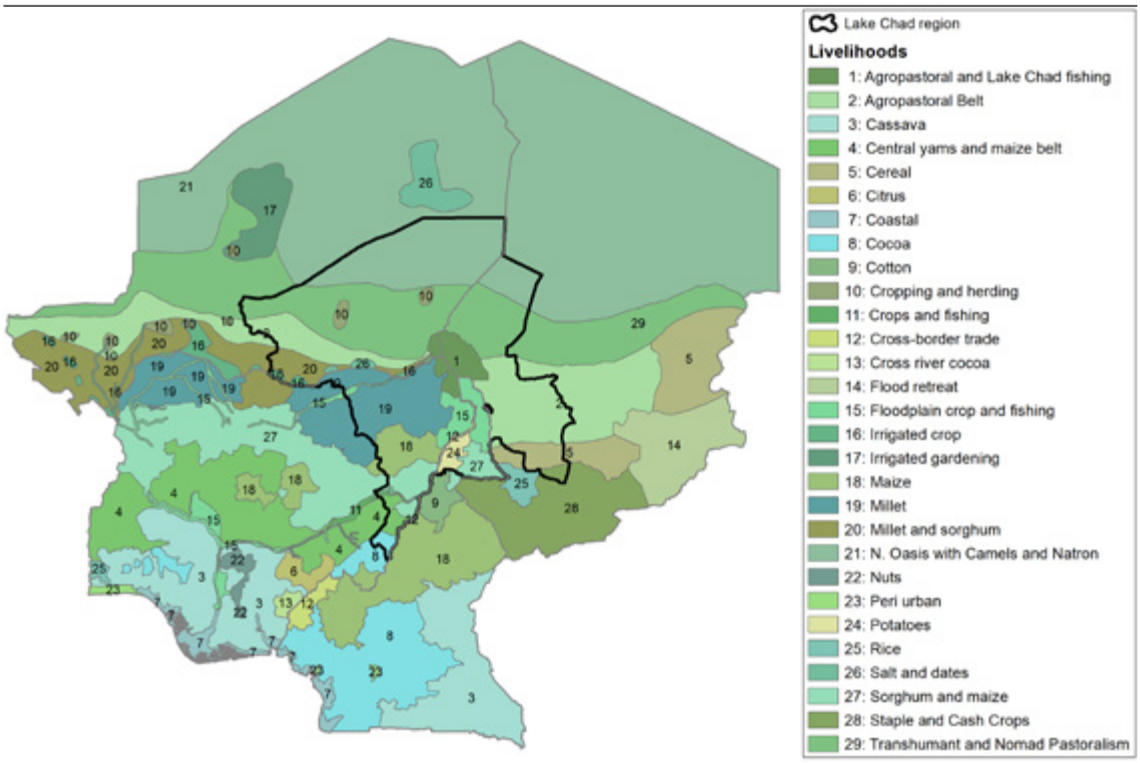
371 Values less than 0.3, which include negative values, are considered background noise such as large areas of the Sahara desert.
372 The World Bank World Development Indicators reports that the share of agricultural added-value GDP is in a range of 15–42 percent.

Livelihood zones for each country are from FEWS. NET. These geographic zones group people with similar patterns considering how people gain access to food and income as well as markets. The map data include the following number of zones: 36 in Nigeria (FEWS NET, 2018), 9 in Chad, (FEWS NET, 2011a), 15 in Niger (FEWS NET, 2011b) and 17 in Cameroon (FEWS NET, 2019a).[373] I aggregate these categories into 29 categories based on the first or dominant crop listed in the description with multiple crops (See Map 7.4).

7.2.5 Conflict data

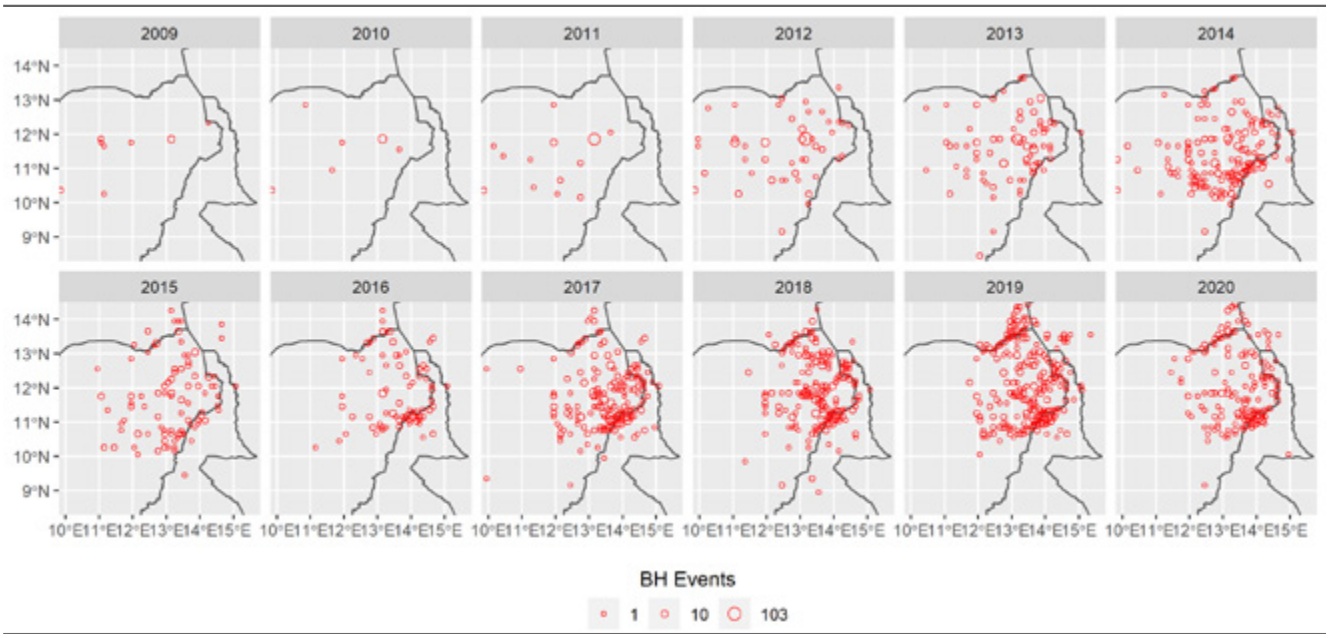
The insurgency by Boko Haram in the Lake Chad area has led to an increase in the number of conflict events and fatalities since 2009 with a notable concentration in the three states of Northeastern Nigeria (See Map 7.5).[374] The ACLED database includes over 4,800 events with more than 35,000 fatalities that are associated with Boko Haram as an actor from 2009 to December 2020. Many conflict events are in close proximity to Maiduguri, which is the state capital of Borno and major commercial center in the Lake Chad region. According to a news source in 2013, approximately 5,000 hectares of agricultural plots with wheat and rice were abandoned near Marte in Borno state, Nigeria. This translated to roughly 200 metric tonnes of wheat according to Abubakar Gabra Iliya, head of the Lake Chad Basin Development Agency.[375] After 2013, conflict events continued to increase in occurrence and spread to include the area across the Nigerian border in the Lake Chad area (See Map 7.5). In Niger, Boko Haram activities target Diffa, Bosso and the small villages along the river Komadougou. In Chad, Boko Haram is present in the islands of Lake Chad as well as attacks in N'Djamena, Guitté, Bo and

Map 7.4: This map illustrates the livelihoods of the four countries, which clusters similar livelihood patterns into a zone



373 The zones for Cameroon were digitized given the lack of response of FEWS NET to provide the georeferenced data and may include small digitizing errors.
374 Violence from Boko Haram increased most notably after the execution of its leader Mohammed Yusuf in July 2009.
375 https://www.pmnewsnigeria.com/2014/03/25/food-supply-crisis-imminent-in-nigeria/

Map 7.5: These maps in the panel show the evolution of the number of events from 2009–2020 defined as Boko Haram



Source: ACLED (Raleigh et al., 2010) (downloaded 2020-05) and author's calculations.

Baga Sola. More recently, Boko Haram has taken refuge in the Sambisa forest, which is South East of Maiduguri, and the swamps of Lake Chad (Magrin et al., 2018). Conflict has taken place, especially in the area in close proximity to Lake Chad. I use the location of conflict events from the Armed Conflict Location & Event Data Project (ACLED) (Raleigh et al., 2010). I summarize the number of events and fatalities by cell.

7.3 Empirical Framework

In a framework following Berg et al. (2018), I first explore the links between market access and two measure of agriculture: cropland area and a local measure of agricultural economic activity. I examine the impact of market access on cropland area using a panel framework and a second model exploring the association between cropland area and local agricultural activity (Agricultural GDP). Given numerous conflict events have occurred in the past decade, I also examine agriculture activity amidst conflict in a panel framework examining the association of the proximity of conflict on cropland area across the entire region as well as night time lights for a sample of local markets nearby Lake Chad.

7.3.1 Cropland expansion across the region

The cropland regression in levels is defined as follows:

$$InCrop_{i,t} = \alpha_0 InM\,A_{i,t-9} + X'_{i,t-9}\theta + D'_i\pi + \delta_t + \epsilon_{i,t} \qquad (3)$$

where $InCrop_{i,t}$ is natural logarithm of the area of cropland in pixel i for time period t, $InMA_{i,t-9}$ is the lagged natural logarithm of the market access indicator is the result of Equation (1), $X_{i,t-9}$ is a vector of control variables at time t, D'_i is a vector of time invariant dummies, and $\epsilon_{i,t}$ is the error term.

Using the same approach to address concerns of reverse causality I employ a lag in the market access index by one period (9 years) as cultivation may influence the placement of new road investments as well as the changes in local population. To account for the local level of population, I include population density estimated by UNEP-GRID Geneva and The World Bank. The travel time to the nearest major port is a measure of proximity to the international market. To account for heterogeneous effects, I include an interaction of the natural logarithm of the market access index with a measure of agricultural suitability and a measure of shrinking land. The regressions include country fixed effects, time dummies, and the interaction between the two as a control for any remaining unobserved heterogeneity.

7.3.2 Local agricultural activity across the region

I also explore the association between cropland area and a measure of local agricultural activity (local agricultural GDP) at the grid cell level with the following regression estimated in levels. The regression is defined as follows:

$$lnAgGDP_{i,t} = \beta_0 lnCrop_{i,t-9} + \beta_1 lnM\,A_{i,t-9} + X'_{i,t-90} + D'_i\pi + \delta_t + \epsilon_{it} \qquad (4)$$

where $InAgGDP_{i,t}$ is natural logarithm of the local agricultural GDP in pixel i for time period t (2010), $InCrop_{i,t-9}$ is natural logarithm of the area of cropland in the previous period of 9 years, $InMA_{i,t-9}$ is the lagged natural logarithm of the market access indicator is the result of Equation (1), $X_{i,t-9}$ is a vector of control variables at time t, D'_i is a vector of time invariant dummies, and $\epsilon_{i,t}$ is the error term.

The other controls are similar to Equation (3). The travel time to livestock markets accounts for proximity to livestock trading. The regressions include country dummies given the agricultural GDP dataset is only available for one time step. A cautionary note is the local agricultural GDP is the result of a cross-entropy model that leverages spatial detail in the subcomponents of agricultural GDP.[376]

376 See Thomas et al. (2019) for more details and model comparisons.

7.3.3 Agriculture amidst conflict nearby Lake Chad

The previous analyses examine the impact of market access over the past three decades; this framework does not account for the lived reality of access to markets given the insurgency of violence on an annual or seasonal basis. The next section focuses on examining agricultural activity amidst conflict.

7.3.3.1 Cropland expansion amidst conflict

I examine the association of distance to nearest conflict event or fatality on local cropland extent during the period 2009 to 2019 for the entire region.

$$lnCrop_{i,t} = \alpha_0 lnDistConf_{i,t-1} + lnDistConf_{i,t-1} \times Y_i + lnNTL_{i,t-1} + lnNTL_{i,t-1} \times S_{i,t-1} + lnNTL_{i,t-1} \times lnM\,A_{i,2008} + X'_{i,t-1}\theta + X'_{i,t-1}0 + D'_i\pi + \delta_t + \epsilon_{i,t} \qquad (5)$$

where $lnCropi,t$, is the natural logarithm of the cropland area in pixel i for time period t in years, $lnDistConf$ is the natural logarithm of the nearest distance to a conflict event or an event with a fatality from pixel i in the previous year $t-1$, $X_{i,t-9}$ is a vector of control variables at time t, D'_i is a vector of time invariant dummies, and $\epsilon_{i,t}$ is the error term. I use a lag in the conflict variables to address reverse casualty. I address the concern about modeling error of local population estimates due to displacement by taking advantage of the annual frequency and high correlation of night time lights with population density. I include lagged night time lights variables to control for size effects. Then, I interact night time lights with shrinking cropland, market access in the previous base year (2008) and natural logarithm of the travel time to nearest livestock market in 2008.

7.3.3.2 Operational status of markets amidst conflict

For a set of markets in the area nearby Lake Chad with reported operational status, I examine the impact of the market operational status on the natural logarithm of night time lights. Then, I introduce a distance to the nearest conflict event from the previous year into the regressions as follows:

$$lnNTL_{i,t} + \alpha_0 Market_{i,t} + \alpha 1 distConflict_{i,t-3} + X'_{i,t-1}\theta + D'_i\pi + \delta_t + \epsilon_{i,t} \qquad (6)$$

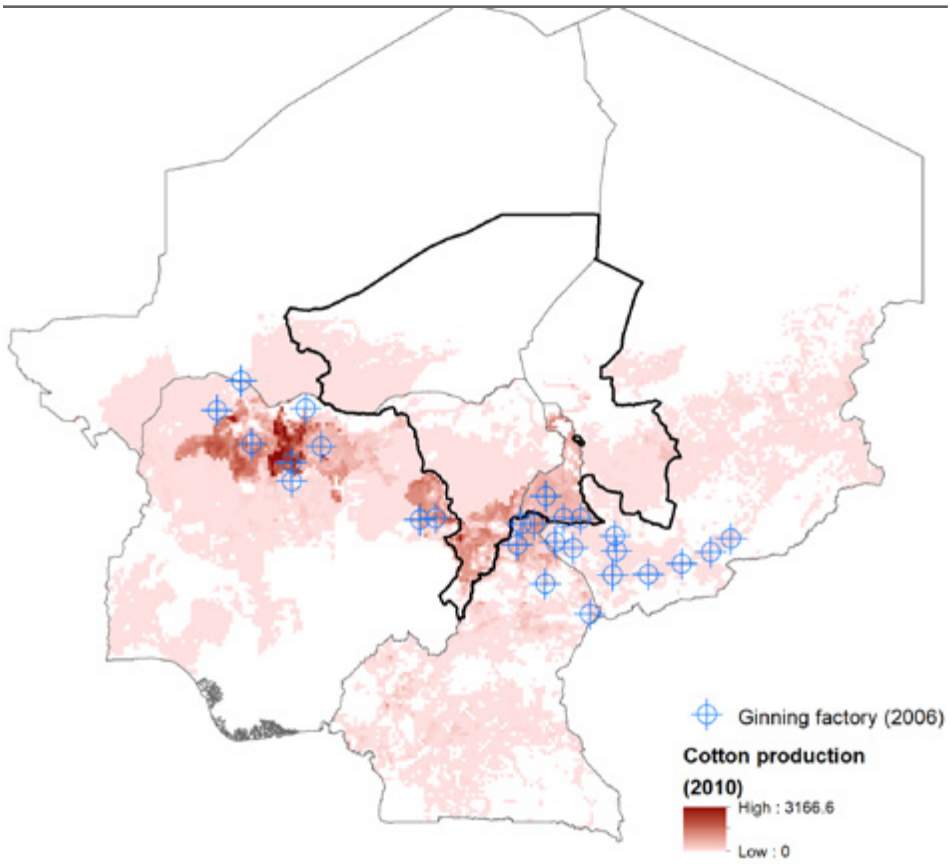
where $InNTL_{i,t}$, is natural logarithm of the sum of night time lights in pixel i for time period t, which is defined as a season of the year (land preparation, sowing and growing, or harvest). $Market$ is the operational status of the local market as normal, below normal or closed. $distConflict$ is the distance to the nearest conflict event in pixel i during the same season of the previous year, $X_{i,t}$ is a vector of control variables at time t, D'_i is a vector of time invariant dummies, and $\epsilon_{i,t}$ is the error term. I include the mean precipitation and its square along with mean greenness during the season as a control, which is used as a proxy for local agricultural productivity.

7.4 Results

7.4.1 Trends in Agriculture

Agriculture is the main sector of economic activity for households and individuals living in the Lake Chad region. For the four countries, Map 7.4 illustrates dominant livelihoods with similar patterns considering how people gain access to food and income as well as markets. The northern areas of Niger and Chad are sparsely populated with activities including salt, dates and trading activities in oases along with nomad pastoralism and transhumance. In southern Niger, where most of the population lives, is an agropastoral belt with millet and sorghum as well as irrigated crops such as Komadougou Irrigated Peppers and Violet de Galmi onions (FEWS NET, 2011b). Northern Nigeria has cultivated areas with diverse crops including millet and sorghum as well as livestock. The area nearby Lake Chad includes flood retreat cultivation and fishing activities. Major cash crops include cotton in the Sahel region where many cotton ginn factories are located (See Map 7.6). Other rainfed cash crops such as bananas and coconuts are located near the ports outside of the Lake Chad area. Maize, cassava, sorghum and millet provide staple crops and are among the highest production in the Lake Chad region.[377]

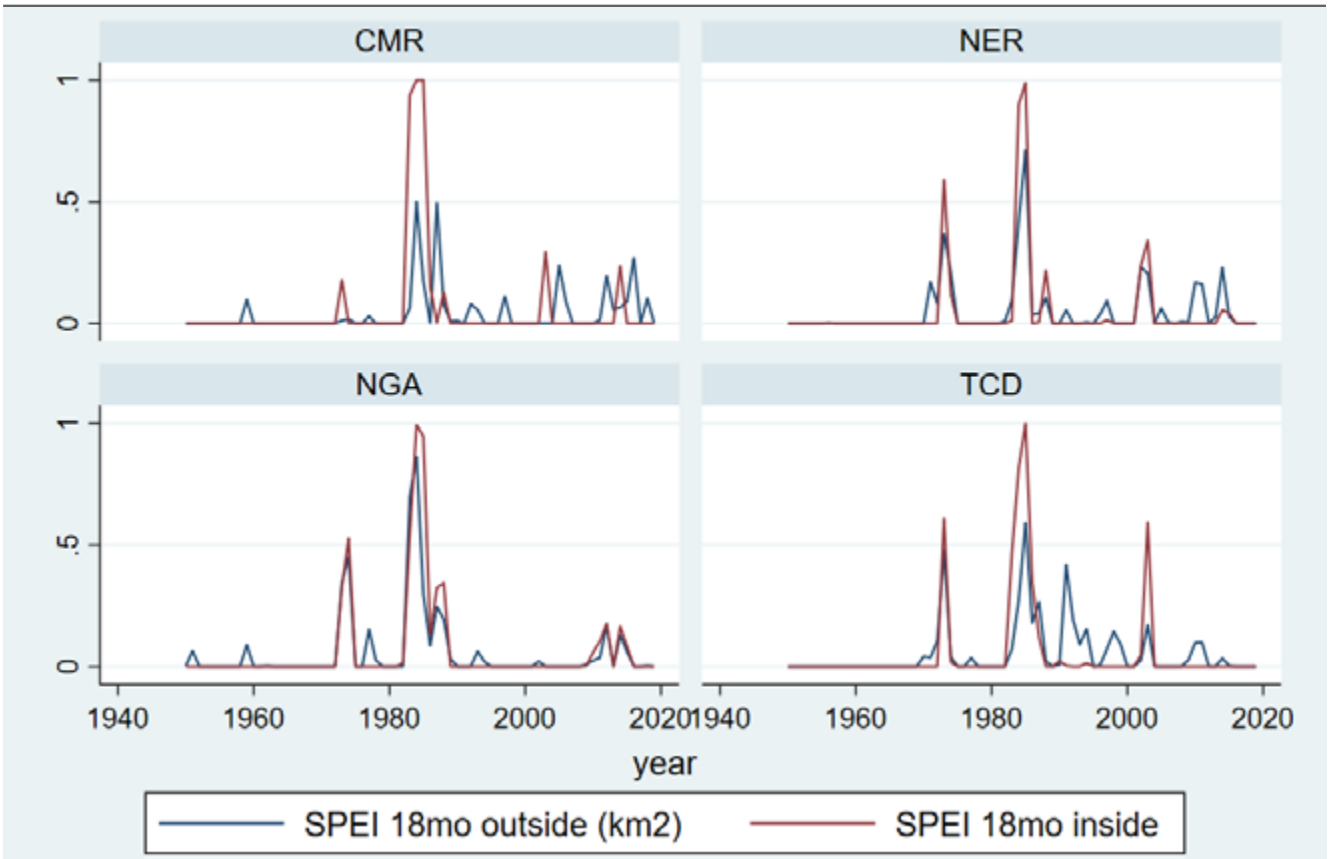
Map 7.6: This map illustrates cotton production from SPAM ca. 2010 (Yu et al., 2020) and ginning factories (OECD, 2006)



377 These results are summarized from the SPAM circa 2017.

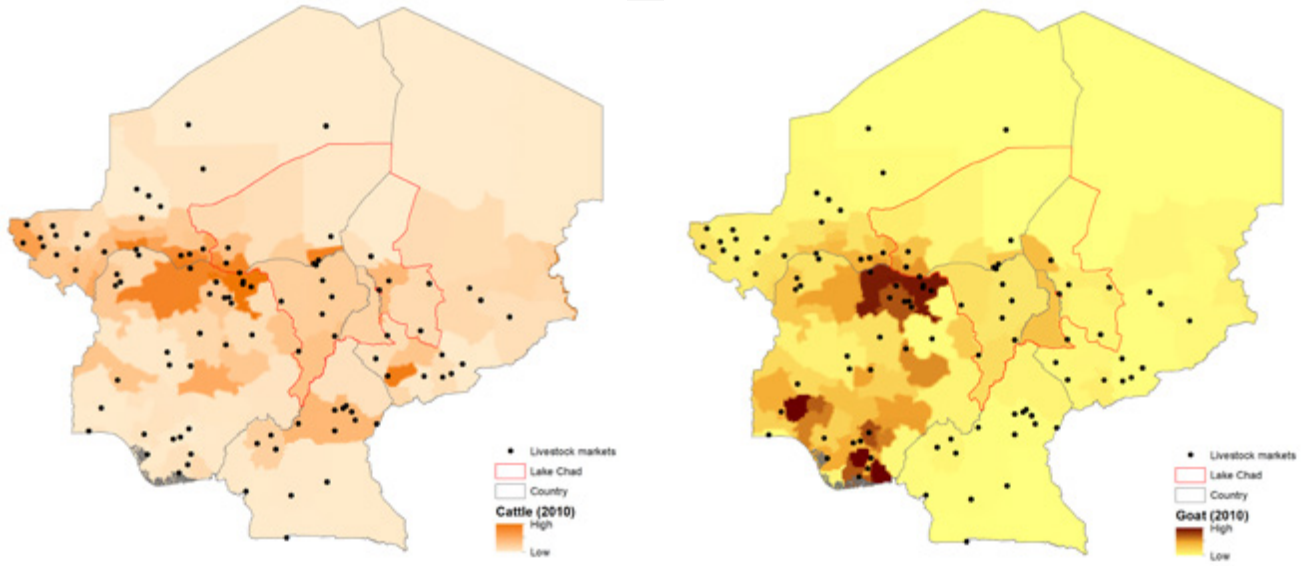
In the region, agricultural production is typically rain-fed and thus dependent on the climate. The levels of rainfall have varied over the past several decades. One can consider three periods of climate since 1960 in the Lake Chad area: a period of high rainfall in the 1960's, low rainfall in 70s to the 90s and the recent period with more variability than the two previous periods. Droughts can impact food availability and timing and a households' ability to consume. Figure 7.1 displays the share of area that exceeds a drought threshold, which is measured by SPEI with 18 month lag, for the Lake Chad study region "inside" and the remaining area in the country "outside". One can see the major drought in the 70s and 80s[378] and the lesser intensity one in the 00s, where the Lake Chad area typically has a higher share of drought compared to the remaining are in the country. However, the period from the 1980s until present has seen some greenness growth as measured from satellite (e.g. Dardel et al., 2014). As shown above, some seasons drought persists, however the opposite case is also true. In 2019, flooding occurred in an area with approximately 220,000 people as the result of heavier-than average rainfall in the fall of 2019. USAID (2020) reported the damage from the floods included infrastructure, crops and restricted access. The area nearby Lake Chad is rural and dependent on hydro-climatic conditions (Nilsson et al., 2016).

Figure 7.1: This graph shows the share of area considered a drought identified from the Standardized Precipitation Evapotranspiration Index (SPEI) at an 18 month time lag (with a value less than or equal to -1.5). This is the result of the algorithm provided by Begueria et al. (2014) using the monthly precipitation and evapotranspiration data version 4 from the Climate Research Unit (Harris et al., 2020)

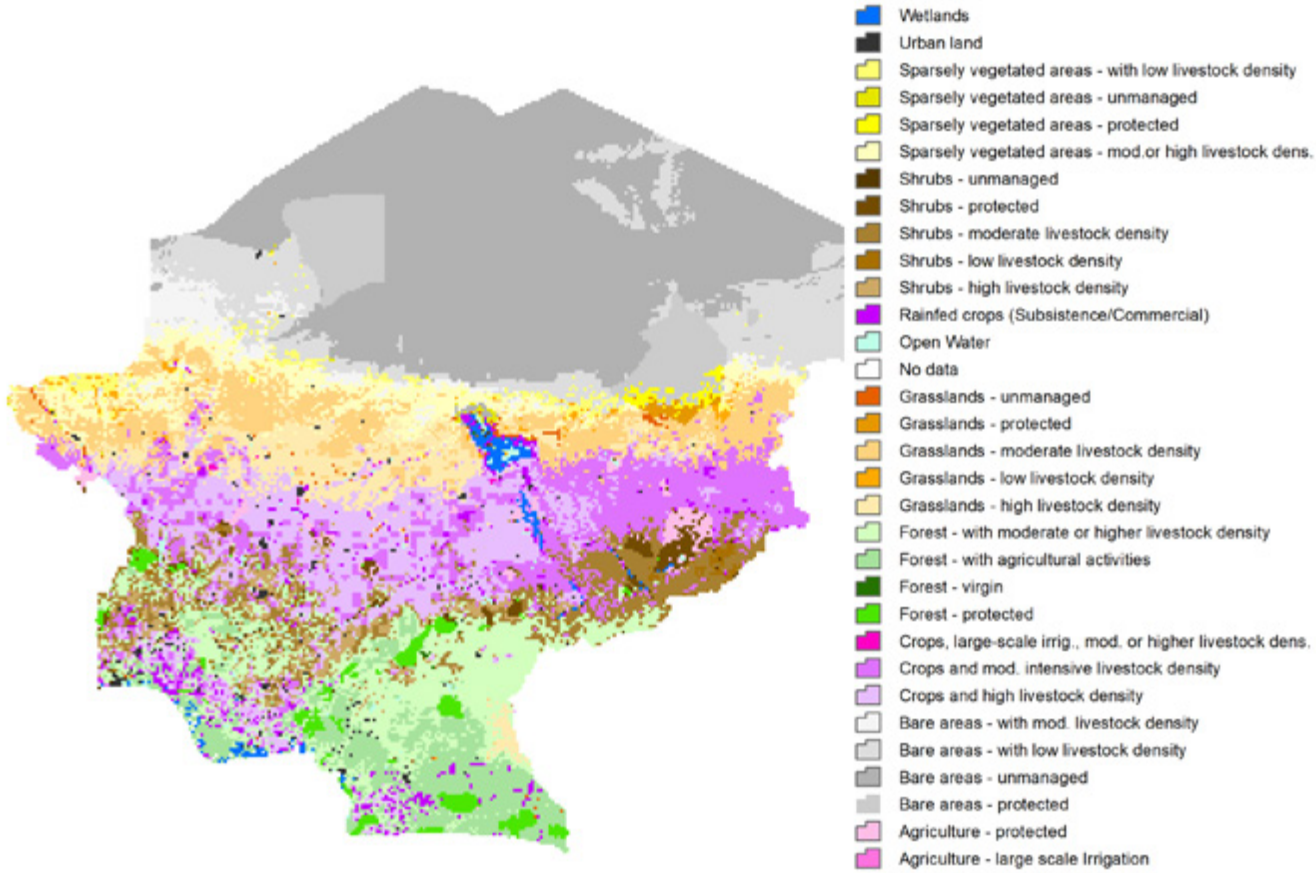


378 Rivers did not flow into the lake in 1973 and 1984 as the result of Sahelian drought (Raji, 1993).

Map 7.7: These maps illustrate the location of livestock markets (black dots) from FEWS NET (2009); Motta et al. (2017) and distribution of cattle from Gilbert et al. (2018) (left) and goat (right) in 2010 from Gilbert et al. (2018) where a darker shade represents higher livestock density



Map 7.8: This map illustrates land use (Nachtergaele et al., 2010) (Version 1.1)



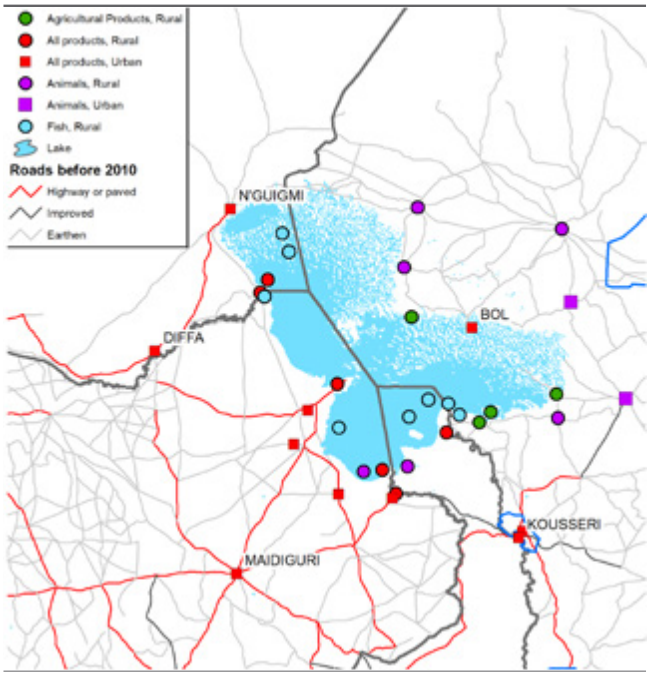
Over the past two decades, arable or cropland areas increased although irrigated lands are limited as measured from satellite imagery. Total cropland area has increased by almost 43,000 km^2 between 1992–2019, where Cameroon and Nigeria have the most relative gain in cropland area compared to Chad and Niger. Irrigated areas represent approximately 5 percent of the cropland area during this period with little growth, which is the likely result of little new investment. The annual growth rate of cropland area for the four countries started at 0.42 percent during the 1992–2001, lessened at 0.31 percent during 2001–2010, and was lower at 0.03 during 2010–2019.The annual growth rate of cropland area for the four countries inside the area nearby Lake Chad started at 0.29 percent during the 1992–2001, lessened at 0.24 percent during 2001–2010, and was slightly negative during 2010–2019.

In addition to cropland, the livestock trade is vital for the region and cross-border trade has long played a role in trade in livestock markets in Africa (de Haan et al., 1999). The distribution of livestock markets and a subnational estimate of cattle is notable in the Lake Chad area (See Map 7.7). Over half of the livestock markets are within 100km of the border and 16 of the 97 livestock markets are located in the Lake Chad area. Nearby Lake Chad, agricultural activities benefit from the connection to markets. Fish routes supply several tonnes of fish everyday to regional hubs of N'Djamena and Maiduguri with an annual estimate of 50,000 to 100,000 tonnes of fish per year (Lemoalle and Abdullahi, eds, 2017). Similarly, livestock trade routes from Chad and Niger pass through Maiduguri onto regional markets and are an important part of the goat and millet trade (WFP, 2016).

Mapping the cropland, livestock, forestry, fishing across the landscape illustrates a mosaic of agricultural activity and management of land (See Map 7.8). The agricultural economy of Nigeria is notably higher than the other three countries. The development of highways in Nigeria coincides with the area with relatively higher agricultural GDP circa 2010; they are the three corridors of Kaduna-Kano (North Central), Lagos-Benin City (South West) and the delta region corridor of Port Harcourt-Enugu (See Map 7.3). The natural logarithm of the distance to nearest paved road in 2008, which is constrained by country, has a negative correlation with natural logarithm of local agricultural GDP of 0.70.

In closer proximity to Lake Chad, road transport connects key local agricultural markets of (i) Bol and N'Djamena in Chad, (ii) Kousseri in Cameroon, (iii) N'guigmi and Diffa in Niger and (iv) Bosso, Niger along with Marte and Monguno via Madiguri in Nigeria. Maiduguri is an important connection for the trade corridors between Nigeria and Cameroon (Kousseri or Maroua) (See Map 7.9). This was especially important in the commercialisation of fishing in Lake Chad linked to the development of road infrastructure (Stauch, A., 1960). For the fishing trade, a number of fish markets exist; the largest fish market was Baga Kawa in Nigeria (prior to Boko Haram), which is a key market town in close proximity of Lake Chad (Magrin et al., 2018).

Map 7.9: This map illustrates local markets in close proximity to Lake Chad by type



Source: Déby Itno et al. (2015).

7.4.2 Market Access

Table 7.1 presents the panel results of market access on cropland area (in levels). The baseline estimation of equation (3) of market access does have a significant positive effect on an increase in cropland across OLS (Columns 1–3) and FE specifications (Columns 4–6) during the period from 1992 to 2019.[379]

The results from new and updated measurements with a focus on the Lake Chad region are in line with previous research by Berg et al. (2018). Given the modest gain in length of paved road, the growth in population, which is a proxy for the size of the market, is the main driver for the increase in market access. A 1 percent increase in market access is associated with a 3.9 per cent increase in cropland area. Given the approximate total of cropland in the four countries is nearly 600,000 km^2, this result implies a growth of around 23,400 km^2 given a 1 percent increase in market access over 9 years. Following Berg et al. (2018), I examine spatial heterogeneity with interactions of market access with yield and a shrinking cropland dummy. The sign of the yield interaction is positive, providing a positive association of the growth in cropland where the land has higher yield of cotton.[380] Also, it is important to note that the area near Lake Chad is landlocked. The results show a connection of cropland area to external markets measured in travel time to the nearest port that are located in Nigeria and Cameroon.

Table 7.1: Estimates of the impact of market access on cropland area

	(1)	(2)	(3)	(4)	(5)	(6)
Ln MA_{t-9}	0.317***	0.0420**	0.0374	0.274***	0.0385*	0.0434*
	(18.96)	(2.72)	(1.80)	(16.50)	(2.39)	(1.99)
Ln MA_{t-9} × Yield			0.0701**			0.0630*
			(2.71)			(2.31)
Shrinking		-0.0920***	-0.0841***		-0.0826***	-0.0706***
		(-14.04)	(-11.65)		(-12.65)	(-9.83)
Ln MA_{t-9} × Shrinking			-0.0322*			-0.0486***
			(-2.43)			(-3.58)
Ln time to $port_{t-9}$		-0.109***	-0.107***		-0.0355***	-0.0332***
		(-14.97)	(-14.75)		(-4.40)	(-4.09)
Ln pop $density_{t-9}$		0.359***	0.359***		0.135***	0.133***
		(97.01)	(97.03)		(36.73)	(36.34)
Mean $Precipitation_t$		-0.114***	-0.111***		-0.187***	-0.182***
		(-6.33)	(-6.16)		(-10.42)	(-10.21)
(Mean $precipitation_t)^2$		-0.0119*	-0.0114*		0.0269***	0.0274***
		(-2.22)	(-2.13)		(5.12)	(5.18)
Country x Year dummies	Y	Y	Y	Y	Y	Y
Observations	133,008	133,008	133,008	133,008	133,008	133,008
R-squared	0.0528	0.532	0.533	0.0528	0.449	0.450

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table presents estimates of OLS (column 1-3) and FE (column 4-6) regressions of the natural logarithm of the sum of rainfed and irrigated cropland area at time t on the natural logarithm of the lagged market access index during the period between 1992 and 2019. The controls included in the OLS regressions (column 3-4 and 5-6) include a dummy variable indicating a decrease in cropland during the previous period (***shrinking***$_{t-9}$), the lagged natural logarithm of time to nearest major port (***Ln time to major port***$_{t-9}$), the average rainfall over the previous five years / 1000 (***Mean precipitation***$_t$) and its square, and country × year dummies. Constants are not shown.

379 Specifically, the panel includes the following years: 1983, 1992, 2001, 2010 and 2019.

380 The yield of cotton is a constant value circa 2010 from the SPAM model. Regressions (not shown) of market access on cropland provide similar results with a positive and significant interaction with the agricultural suitability.

A 1 percent decrease in this time is associated with a 3.6 percent increase in cropland area.

Next, Table 7.2 presents the results examining the association of cropland expansion on local agricultural GDP from the Equation (4). As mentioned earlier, this result is a descriptive association due to potential endogeneity concerns about the modeling of the local agricultural GDP measure. Cropland does have a significant positive effect on an increase in local agricultural GDP in OLS specifications.[381] Following Berg et al. (2018), I examine the relationship with and without market access. I find a positive and significant coefficient for market access even beyond the effect of cropland expansion controlling for time to port and time to nearest livestock market.

Table 7.2: Estimates of the impact of market access on Agricultural GDP

	(1)	(2)	(3)
Ln crop$_{t-9}$	0.950***	0.342***	0.342***
	(245.43)	(71.44)	(71.50)
Ln MA$_{t-9}$			0.0872***
			(3.92)
Ln time to port$_{t-9}$		-0.312***	-0.302***
		(-21.67)	(-20.46)
Ln time to livestock markets$_{t-9}$		-0.0232***	-0.0242***
		(-3.27)	(-3.41)
Ln population density$_{t-9}$		0.316***	0.315***
		(41.44)	(41.19)
Mean precipitation$_t$		1.234***	1.245***
		(37.78) (37.74)	
(Mean precipitation$_t$)^2		-0.259***	-0.261***
		(-27.54)	(-27.54)
Country x Year dummies	Y	Y	Y
Observations	33,252	33,252	33,252
R-squared	0.602	0.878	0.878

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table presents estimates of OLS (column 1–3) regressions of the natural logarithm of Agricultural GDP (ca. 2010) on the natural logarithm of the sum of rainfed and irrigated cropland area (*Ln cropland*$_{t-9}$) and the lagged market access index (*Ln MA*$_{t-9}$). The controls included in the OLS regressions include the lagged natural logarithm of time to nearest major port (*Ln time to major port*$_{t-9}$), the lagged natural logarithm of time to nearest livestock market (*Ln time to livestock*$_{t-9}$), the lagged natural logarithm of time to nearest ginn factory (*Ln time to ginn factory*$_{t-9}$), the average rainfall over the previous 5 years * 1000 (*Mean precipitation*$_t$) and its square, population density (*Ln pop density*$_{t-9}$), and country × year dummies. Constants are not shown.

These two analyses provide suggestive evidence for the positive impact of market access on cropland expansion and local agricultural economic activity in the countries comprised of the Lake Chad region. Given the conceptual framework, these results used a lagged approach with a period of 9 years. Remarkably, the current development status in the region has changed since the onset of Boko Haram in 2009. In the next section, I examine the association of the location of conflict events on cropland and the association of operational status of markets on night time lights.

7.4.3 Market status and conflict nearby Lake Chad

Recent developments with the variation in environmental conditions and conflict pose challenges for agricultural activity. From the suggestive evidence above, market access is associated with an increase in cropland area (extensive margin), however this result does not incorporate short-term shocks or the uncertainty to travel to market, especially related to the proximity of conflict events.[382] The discussion below focuses on the Boko Haram conflict regionally and then geographically on an area in close proximity to Lake Chad with more detailed data (e.g. market data) to contextualize current development with remotely sensed measures.

7.4.3.1 Cropland amidst conflict

As stated above, the Boko Haram insurgency started near Maiduguri in 2009 (see Map 7.5). Numerous reports state the destruction of cropland and infrastructure as

381 The local agricultural GDP data are only available circa 2010.

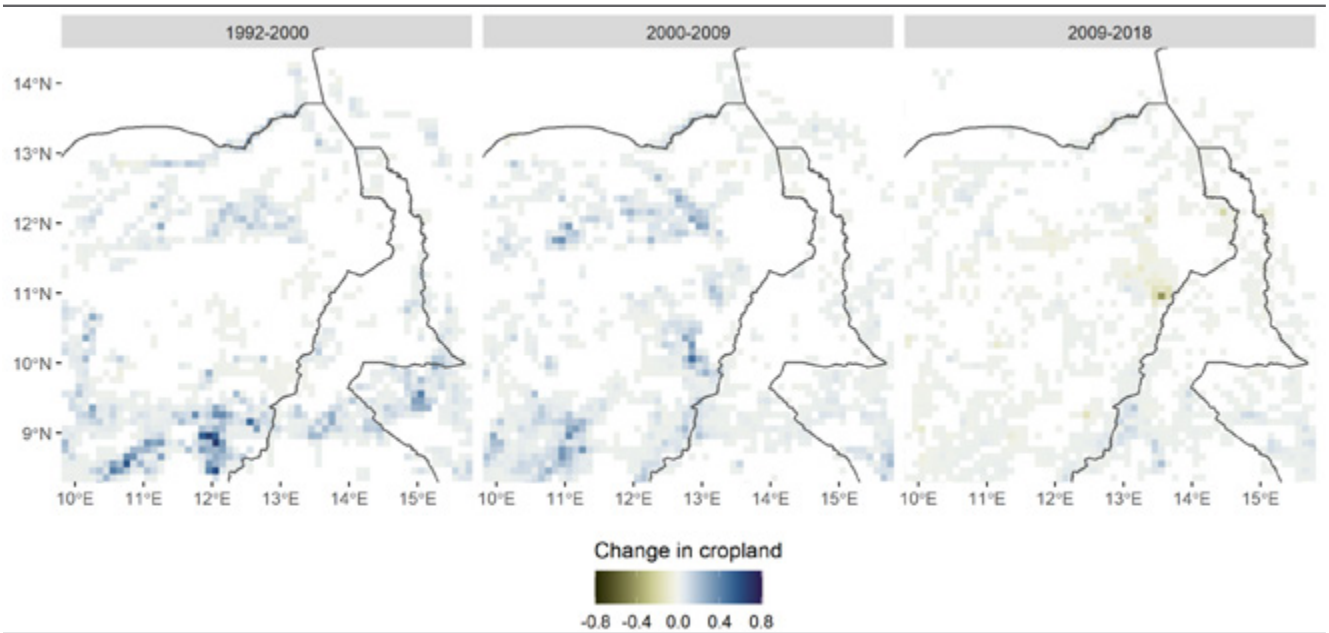
382 The travel time assumes fastest route and does not include any measures of delays or road blocks. For example, Van Der Weide et al. (2018) incorporate road closure obstacles in the travel time analysis to quantify the impact of market access on local GDP in the West Bank.

Table 7.3: Estimates of the impact of the proximity of conflict on cropland area

	(1)	(2)	(3)	(4)
Ln NTL_{t-1}	0.0154***	0.0176***	0.0139***	0.0163***
	(4.50)	(5.12)	(4.04)	(4.73)
Ln dist to $event_{t-1}$		0.00413***		0.00576***
		(9.60)		(13.38)
Ln dist to $event_{t-1}$ × Yield		0.00237***		0.00162***
		(17.26)		(12.04)
Ln NTL_{t-1} × $Shrinking_{t-1}$	-0.0223***	-0.0222***	-0.0225***	-0.0223***
	(-15.70)	(-15.63)	(-15.77)	(-15.71)
Ln NTL_{t-1} × Ln MA_{2008}	0.00711*	0.00721*	0.00686*	0.00688*
	(2.50)	(2.54)	(2.40)	(2.42)
Ln NTL_{t-1} × Ln time to $livestock_{2008}$	-0.00250***	-0.00289***	-0.00223***	-0.00262***
	(-4.06)	(-4.68)	(-3.62)	(-4.25)
Mean $precipitation_t$	0.0126*	0.0182***	-0.0127**	-0.00844
	(2.55)	(3.66)	(-2.65)	(-1.75)
$(Mean\ precipitation_t)^2$	-0.00551***	-0.00724***	0.00113	0.000184
	(-3.54)	(-4.62)	(0.74)	(0.12)
Country x Year dummies	Y	Y	Y	Y
Observations	365772	365772	365772	365772
R-Squared	0.326	0.327	0.180	0.199

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Notes: This table presents estimates of OLS (1-2) and FE (3-4) regressions of the natural logarithm of cropland area at time ***t*** (in years) on the natural logarithm of the distance to the nearest conflict event ($Ln\ dist\ to\ event_{t-1}$), night time lights ($Ln\ NTL_{t-1}$), the average rainfall ($Mean\ precipitation_t$) and its square. Constants are not shown.

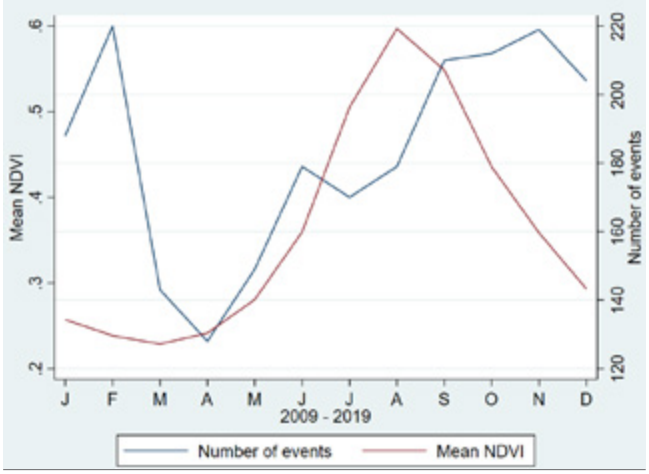
Map 7.10: This panel set of maps shows the evolution of cropland for three distinct periods: 1992–2000 (left map); 2000–2009 (center map); 2009–2018 (right map)



Source: ESA.

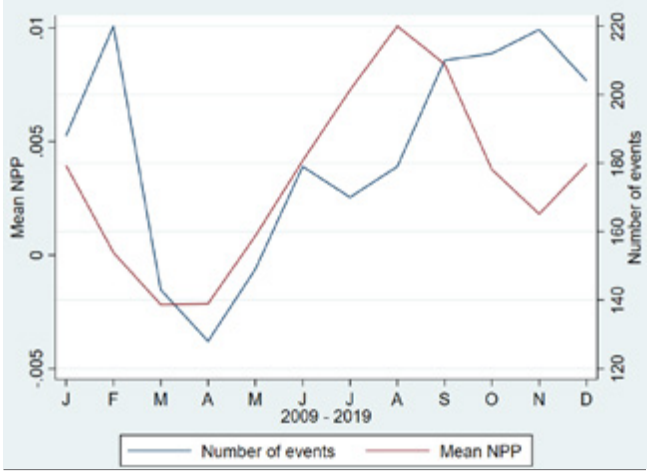
Figure 7.2: Two figures illustrating the seasonality of the number of conflict events with NDVI (a) and NPP (b)

(a) This graph displays the monthly frequency of conflict events from Boko Haram and the mean level of greenness of vegetation, as measured by NDVI.



Sources: Raleigh et al. (2010); NASA (2020b) and author's calculations.

(b) This graph displays the monthly frequency of conflict events from Boko Haram and the mean level of Net Primary Productivity, as measured by NPP.



Sources: Raleigh et al. (2010); NASA (2020c) and author's calculations.

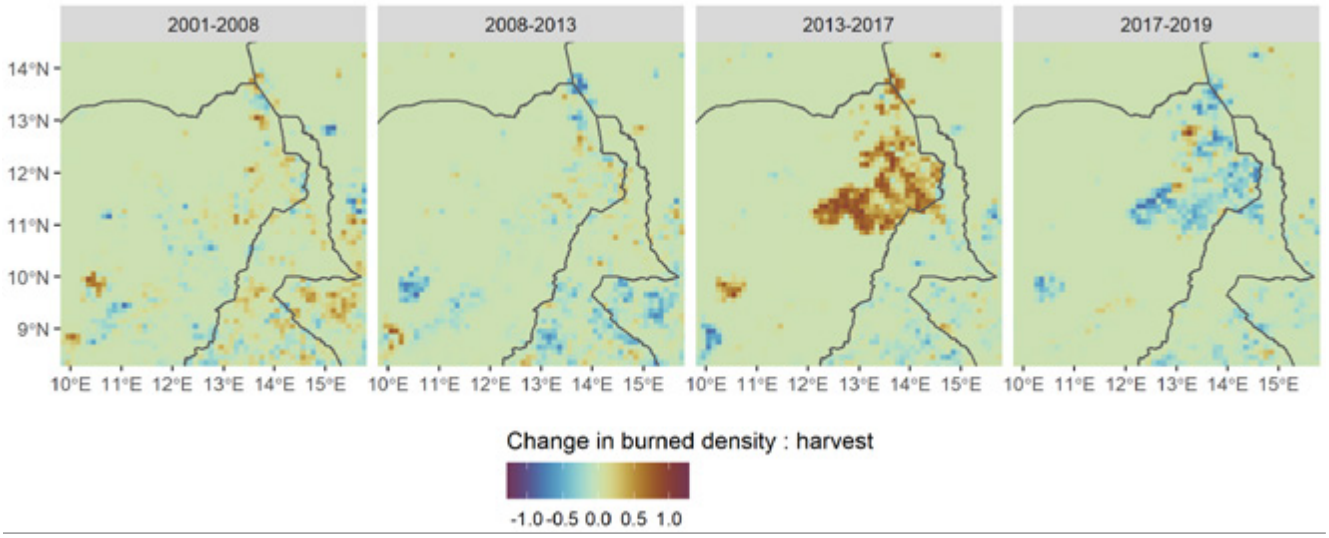
well as the undermining the supply routes of agricultural inputs (e.g. FAO, 2017; Jelilov et al., 2018). I find suggestive empirical evidence of the decrease in cropland as derived from satellite land use classification in areas near conflict events. During the period 2009 to 2018, cropland area in North East Nigeria decreased, even though the previous two periods indicated some growth in cropland area (See Map 7.10). Table 7.3 presents the results of the OLS and FE regression of the impact of the proximity of conflict from Boko Haram on cropland area from 2009 to 2019. The results highlight an association of an increase of cropland area away from the natural logarithm distance to the nearest event or fatality during the previous year.

Given the seasonality of agricultural production, Figure 7.2 shows measures of crop phenology along with the frequency of Boko Haram conflict events. Focusing on the three Northeastern states in Nigeria, these events have two peaks: one during the harvest and another in the land preparation stage.

Recent research finds that the rise of Boko Haram results in more agricultural burning (Jedwab et al., forthcoming), which has been associated with agricultural activity due to the common practice of burning fields for clearing and (short-term) nutrients (Blankespoor et al., forthcomingb). Map 7.11 shows the change in burning activity since 2001 in four time periods. The first period shows the variation in burned areas before Boko Haram, whereas the second panel map illustrates a reduction in burned density. Notably, the third panel shows a concentration of burned area nearby Maiduguri and Dikwa in Nigeria that may be attributable to both clearing of fields and conflict events (e.g. the burning of buildings), whereas Northern Cameroon indicates reduction in activity relative to 2013. The last panel of data (2017–2019) shows an attenuation of these burned areas. So, it is important to note that this measure can capture both agricultural activity and conflict, so it is necessary to examine the description of the conflict events.[383]

383 The ACLED database include a description of conflict events that note burning of buildings or razing village(s).

Map 7.11: This panel map illustrates the distribution of burned density during the harvest season



Source : MODIS.

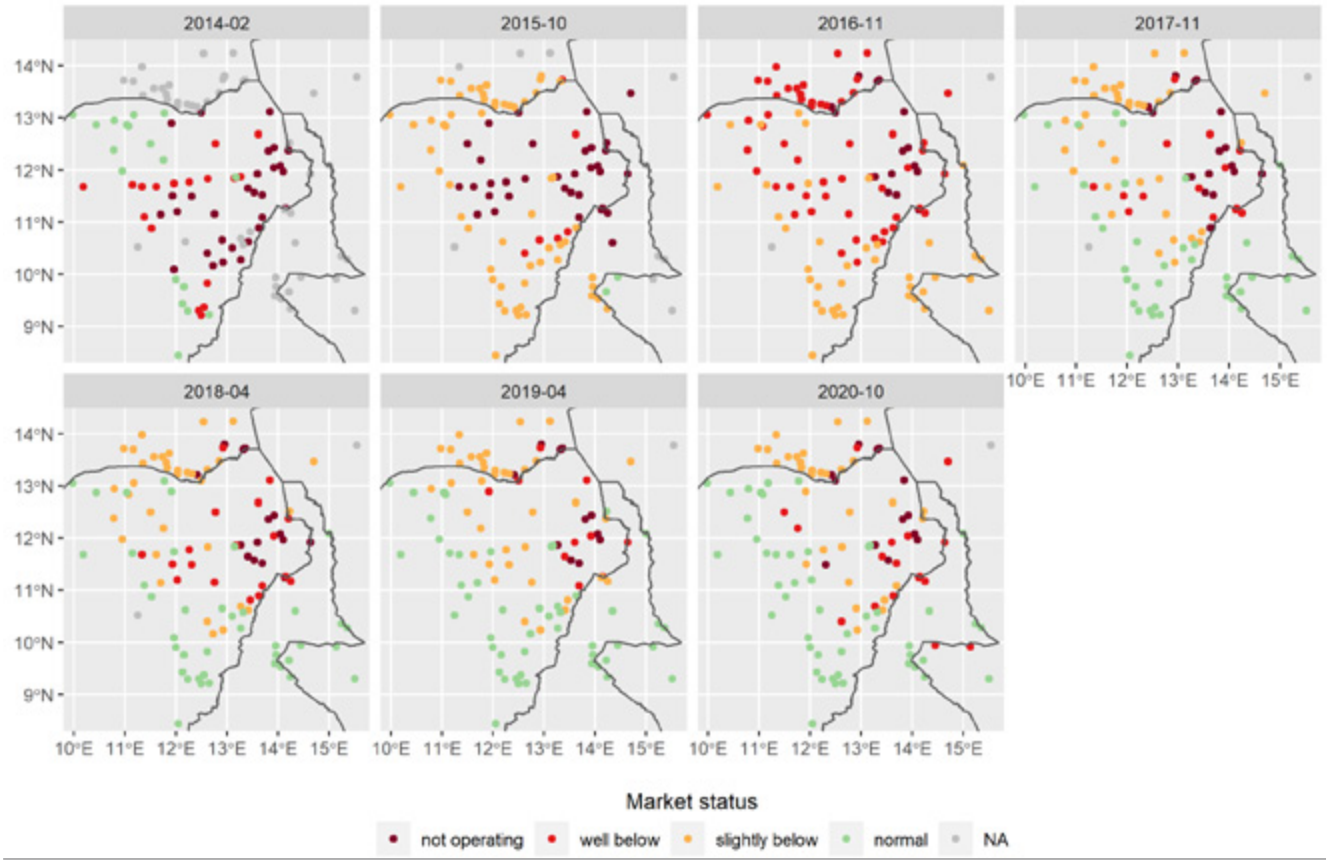
7.4.3.2 Markets amidst conflict

Previous analysis associated the impact of Boko Haram on the operational status of local markets (Van Den Hoek, 2017). The spatial concentration of Boko Haram events was primarily in Northeast Nigeria. Although the monitoring of the markets from FEWS NET started only in 2014, conflict events already took place by Boko Haram at local markets in Nigeria, especially in Borno state (Awodola and Oboshi, 2015).[384] Map 7.12 illustrates the evolution of market status using market data from 2014–2020 based on FEWS NET in Van Den Hoek (2017) with additional digitized time periods from FEWS NET (2019b, 2020).[385] Before 2014, nearly all of the conflict events from Boko Haram took place in Nigeria (Raleigh et al., 2010; Jedwab et al., forthcoming). Many markets were not operating from 2014 to 2016 despite regained territory from some recovery efforts in 2015 from West African troops. Physical damage also took place to market infrastructure, for example, over 650 shops were reported as damaged in Damaturu, Yobe, Nigeria (Mercy Corps et al., 2017). In addition to the indirect and direct impacts of Boko Haram, the Nigerian government made recommendations for some markets to close given the sites are targets for attacks (on civilians) (FEWS NET, 2015). Markets in the Diffa region were officially shut down to impede supply routes to the insurgents and markets in the Far North of Cameroon closed in response to repeated suicide bomber attacks (FAO, 2017). From 2017–2020, several markets on the fringe operated with a slightly below or normal status. Notably, markets in close proximity to Lake Chad were well below or not operating. More recently in 2020, markets in Chad near the border with Cameroon and Nigeria were not operating. Food and Agriculture Organization of the United Nations (FAO) reports that the conflict situation continue to pose challenges for household to access land and agricultural inputs.

Table 7.4 presents the panel results of operational status on the natural logarithm of the mean of monthly night time lights during the season of the year. The baseline estimation of equation (6) of the operational market status compared to the reference closed market does have a significant positive effect on an increase in night time lights for both normal and below normal

384 ACLED database has 23 events with "market" in the notes between 2012 and 2013.
385 The first available year is 2014 along with updates at irregular intervals.

Map 7.12: This panel set of maps shows the evolution of market status in and near Northeast Nigeria with a selection for each year from 2014 to present with the month that the report was published



Source : Van Den Hoek (2017); FEWS NET (2019b, 2020) and author's calculations.

Table 7.4: Estimates of the operational status of local markets on night time lights

	(1)	(2)	(3)	(4)
Market : below$_t$	0.0122**	0.00699	0.0117**	0.00670
	(0.00484)	(0.00487)	(0.00483)	(0.00472)
Market : normal$_t$	0.0182**	0.0155**	0.0171**	0.0147*
	(0.00799)	(0.00727)	(0.00825)	(0.00757)
Ln dist. to conflict event$_{t-3}$		0.00784*		0.00781*
		(0.00418)		(0.00451)
Mean NDVI$_t$	0.170***	0.195***	0.176***	0.202***
	(0.0308)	(0.0331)	(0.0318)	(0.0332)
Precipitation$_t$	-0.531***	-0.677***	-0.532***	-0.676***
	(0.0870)	(0.107)	(0.0911)	(0.111)
(Mean precipitation$_t$)^2	0.662	1.224*	0.619	1.149
	(0.643)	(0.673)	(0.674)	(0.713)
Country x Year dummies	Y	Y	Y	Y
Observations	1,840	1,533	1,840	1,533
R-Squared	0.189	0.180	0.189	0.181

Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.010

Notes: This table presents estimates of OLS regressions (column 1-2) and FE (column 3-4) regressions of the natural logarithm of night time lights at time t (a season in a year) on the operational status of the local market *Market: Normal* and *Market : below* with the reference group defined as closed during the period between 2015 and 2020. The controls included in the regression include: greenness as measured by the mean Normalized Difference Vegetation Index *Mean ndvi*, precipitation *Mean precipitation* and its square *Mean precipitation*^{2} and country × year dummies. Constants are not shown.

market status across the OLS (Columns 1–2) and FE specifications (Columns 3–4). The normal market status has a higher coefficient than below normal market status, which is inline with expectations.

These results show that a normal operation status is associated with a 1.8 percent higher night time lights compared to the reference closed status. The natural logarithm to the nearest conflict event in the same season of the previous year is positive, whereby market locations farther from the conflict have on average higher night time lights. I find similar results for a one year lagged market status (results not shown). A report by Mercy Corps et al. (2017) stated that destroyed market outlets can typically take 9 to 12 months to reopen. Furthermore, findings from the report include 80 percent of interviewed farmers responded that their preferred or most frequented market closed during the insurgency where women and IDP and returnee farmers experienced a slightly higher incidence of market closures compared to the overall average. At the time of writing, the number of conflict events nearby Lake Chad continues at high levels and limits economic opportunities of displaced and conflict-affected households to earn income and now typically include firewood sales, petty trade, and construction labor (FEWS NET, 2021).

7.5 Conclusion

Agriculture is important for the economies of the countries in the Lake Chad region. Farming, herding and fishing provide essential economic activity for many households. Using over three decades of remotely sensed and geospatial panel data to gain insight on agricultural activities, these results provide evidence that an increase in market access is associated with an increase in cultivated land and local agricultural economic activity. Given the modest increase in length of paved road during this period, I find the increase in market access is mainly driven by the growth in population rather than an improvement in roads, which is suggestive that growth in cultivated land is responsive to local demand similar to the findings in Berg et al. (2018). The findings of heterogeneous effects that an increase in market access in areas of shrinking cropland will further reduce cropland area is inline with Berg et al. (2018). Similarly, I find a positive association of market access with agricultural GDP using newly available local estimates.

Although more land is under cultivation, the satellite derived measures of rainfed and irrigated cropland show little gains in irrigated land since 1992. It remains an important question to investigate for further examination whether or not gains in yield have corresponded commensurately with the increase in cultivated land.

Even so, conflict can attenuate gains with negative impacts whereby the proximity of conflict events in the previous year lessens cropland expansion over the entire region and lessens night time lights in local markets. I find that the normal and below normal operational status of markets is associated with higher night time lights compared to closed markets.

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Technical Paper 7. Trade Patterns and Trade Networks in the Lake Chad Region

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8.1 Introduction

The Lake Chad Region (LCR) is an economically interdependent area that encompasses parts of Cameroon (Extrême-Nord), Chad (Chari Baguirmi, Hadjer Lamis, Kenam, and Lac), Niger (Diffa and Zinder), and Nigeria (Adamawa, Borno, and Yobe). The region is characterized by strong historical, ethnic, cultural, and political ties, as well as commercial linkages that extend across its porous borders. Indeed, many if not most of the cross-border exchanges are not recorded in official import and export statistics.

Informal trade is widespread throughout Africa (Bouet, Pace, and Glauber 2018; World Bank 2020), particularly if formal state institutions are under stress. Traders try to avoid import or export declarations as well as border taxes, and customs and other border agencies often tolerate the cross-border trade of small consignments without the need to comply with formal procedures. This does not necessarily mean that these trade flows go untaxed, though. Border officials might levy fees that do not have a legal basis, and state or local authorities often ask for informal payments at roadblocks or in marketplaces.

The LCR is far from a seaport and, hence, heavily landlocked. This condition means that the cost of connecting to international markets is high. As a result, consumers in the LCR pay a high price for imports from global markets, whereas producers in the region get a low price for their exports to international clients. The region faces other challenges that stress its production base and depress economic development. These challenges include erratic weather patterns with frequent periods of drought, as well as environmental degradation of the lake. The most important threat to the well-being and the livelihood of the population in recent years has been the deteriorating security situation, though.

Conflict and violence related to the rise of the Boko Haram movement and counterinsurgency measures taken by the government have severely affected economic activity and cross-border trade in the LCR. Official border crossings have been closed, the movement of people has been limited, and the supply of agricultural inputs, such as N fertilizer and fuel, has been restricted. These impediments and the insecurity of traditional trade corridors have triggered a shift toward alternative, longer trade routes, thereby increasing transaction costs. Yet despite the insecurity-related challenges, cross-border trade continues at a reduced level through formal and informal channels with crops and livestock from Cameroon, Chad, and Niger being supplied to markets in Nigeria in exchange for cereals and semifinished or finished merchandise from Nigeria.

There is a risk that a vicious cycle will develop around trade and conflict in the LCR. Conflict and insecurity reduce trade, with adverse consequences for economic growth and household incomes. Increased poverty, in turn, incites discontent and the willingness to join rebel groups, which further fuels conflict. Breaking this cycle requires that the authorities encourage and support productive activities so that the population has prospects of an improving economic situation and, thus, a stake in a peaceful future.

The following analysis describes and assesses the trade patterns and trade networks in the LCR on the basis of available information from national authorities, international organizations, and academic observers. The focus is thereby on comparisons between the current situation, which is marked by the Boko Haram insurgency and countermeasures taken by the authorities, with the "normal," pre–Boko Haram period. The paper aims to highlight the effect of the conflict situation on economic activity and cross-border trade and thereby help identify strategies that can be used to improve the livelihood of the LCR population. Unfortunately, quantitative information on economic activity and developments in trade flows in the region is virtually absent, so the discussion has often

to fall back to estimates or rely on anecdotal evidence. These data should be interpreted with care.

8.1.1 Trade policies and institutions

The Lake Chad region extends across four countries that use different currencies for trade transactions. Nigeria uses the naira, and Cameroon, Chad, and Niger use the franc. In practice, these different means of exchange do not pose a major obstacle to cross-border trade, though, as traders in the LCR are used to operating in different currencies in parallel and will often accept payment in a currency other than their own.

Another institutional difference is that the four countries are members of different regional trading blocs. Cameroon and Chad are members of the Economic and Monetary Community of Central Africa (CEMAC) and the Economic Community of Central African States (CEEAC), whereas Niger and Nigeria are part of the Economic Community of West African States (ECOWAS). Whereas trade policies and procedures are to a large extent harmonized within the regional trade agreements (RTAs), this is not the case across RTAs. For example, the import tariffs applied by Cameroon (CEMAC) are generally higher than those charged on imports into Niger and Nigeria (Table 8.1). The fact that different trading blocs meet in the LCR makes formal trade integration between the neighbors more difficult, as other countries in the respective blocs would have to agree to any trade policy changes. That said, all four countries are signatories of the African Continental Free Trade Area (AfCFTA), which promises to reduce the remaining tariff and nontariff barriers to intra-African trade and harmonize trade procedures over time. To advance this longer-term goal, members of ECOWAS and CEMAC could discuss and implement trade facilitation and integration measures in the region, which might, for example, lead to the adoption of provisions similar to the ECOWAS Trade Liberalization Scheme (ETLS). The ETLS involves visa-free movement of persons and an exemption for agricultural and livestock products as well as handicrafts from the requirement to provide a certificate of origin. As long as the tariff and nontariff measures of ECOWAS and CEMAC are not fully aligned, the aforementioned provisions could be applied on a reciprocal basis.

Given the preponderance of informal cross-border transactions in the LCR, official import and export procedures seem to be handled flexibly. A recent World Bank study reports that at the Figuil border crossing between Cameroon and Chad, tariff levels are applied differently depending on the officials in charge, the truck

Table 8.1: Average MFN Applied Duties by Product Groups, 2019

	Cameroon	*Niger*	*Nigeria*
Animal products	21.8	24.5	24.5
Dairy products	24.8	17.2	17.2
Fruits, vegetables, plants	27.0	17.8	17.8
Coffee, tea	29.9	18.5	18.5
Cereals and preparations	21.4	13.6	13.6
Oilseeds, fats, and oils	19.8	11.1	11.1
Sugars and confectionery	20.6	12.6	12.6
Beverages and tobacco	27.3	17.4	17.4
Cotton	10.0	5.0	5.0
Other agricultural products	16.4	9.6	9.6
Fish and fish products	25.7	16.0	16.0
Minerals and metals	17.1	11.6	11.6
Petroleum	9.6	7.7	7.7
Chemicals	11.4	7.2	7.2
Wood, paper	20.5	11.2	11.2
Textiles	19.7	16.1	16.1
Clothing	30.0	20.0	20.0
Leather, footwear	20.9	12.3	12.3
Nonelectrical machinery	12.1	6.8	6.8
Electrical machinery	17.2	11.2	11.2
Transport equipment	16.0	8.3	8.3
Manufactures, n.e.s.	22.1	14.2	14.2

Source: WTO database on Tariff Profiles, 2019.
Note: No data are available for Chad, but rates should be identical to Cameroon/CEMAC. CEMAC = Economic and Monetary Community of Central Africa; MFN = Most Favored Nation; n.e.s. = not elsewhere specified.

size and load, or the time of day (World Bank, 2018a). Also, guidance notes from the customs authority leave substantial room for interpretation and, hence, digression by officials, which can facilitate trade but can also enable demands for informal payments.

According to Cantens and Raballand (2017), this flexibility is typical for fragile borderlands. Informal agreements with headquarters provide leeway for local customs officers to adjust the fiscal burden on traders to the prevailing circumstances. Importers meet regularly with customs officials to negotiate and agree on an acceptable tariff and tax burden. These arrangements make it possible to reduce clandestine border crossings and the associated risks of detection by border patrols or encounters with rebel fighters, while providing state authorities with a certain amount of tax revenues.

8.1.2 International connectivity

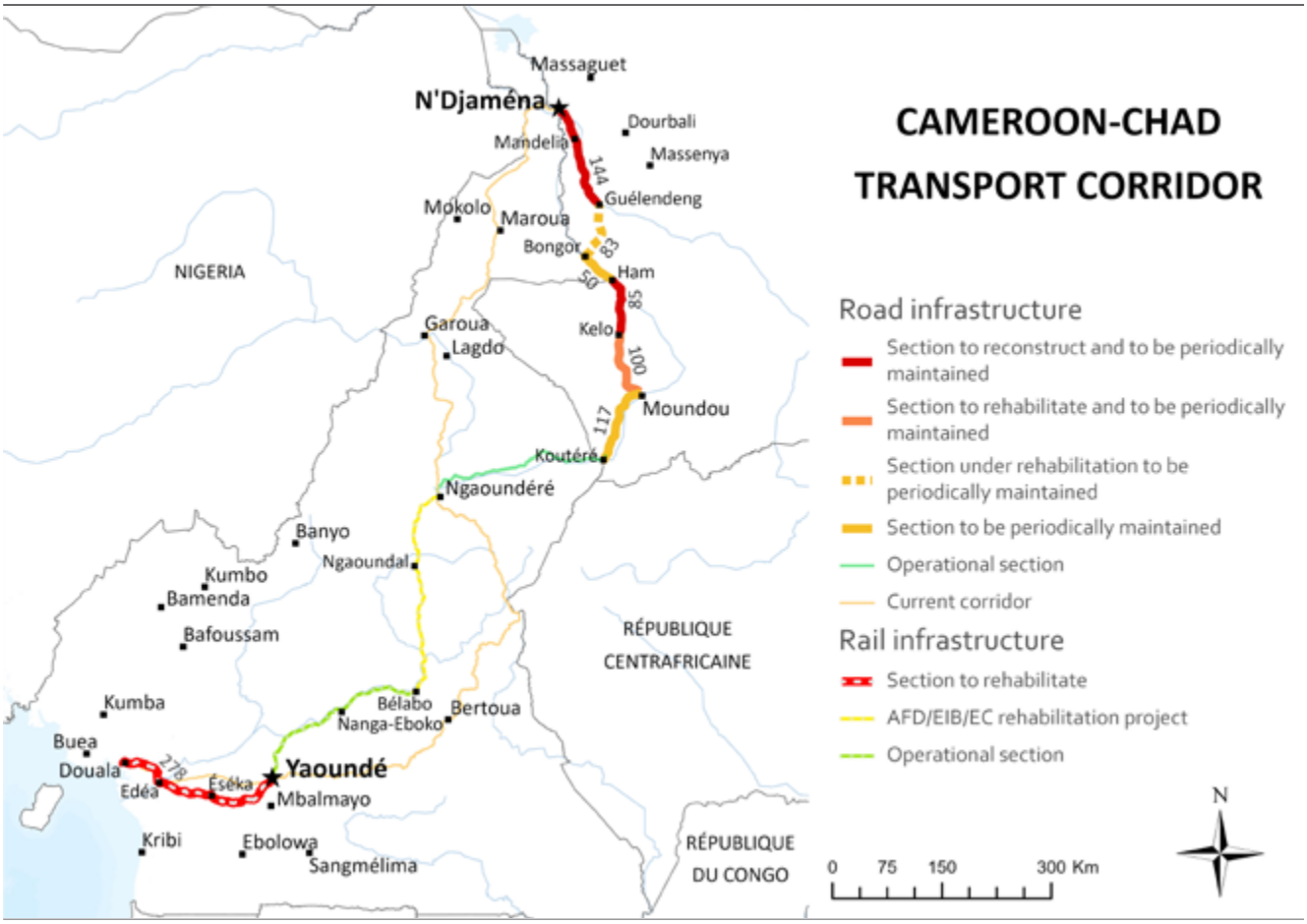
The Lake Chad region is heavily landlocked. The two main consumption centers in the region, Maiduguri and Ndjamena, are located more than 1,300 kilometers (km) from the nearest gateway seaport. The trade corridor from Port Harcourt to Maiduguri is 1,370 km long; the one from Lagos to Maiduguri, 1,530 km; and the one from Douala to Ndjamena, 1,800 km. For comparison, in West Africa, the distance from Abidjan to Bamako amounts to "only" 1,115 km, and in East Africa, the trade corridor from Mombasa to Kampala is "merely" 1,165 km long. The remoteness of the LCR means that trade transaction costs are high and thus imported goods from Europe, Asia, and the Americas will be relatively expensive in local markets, while goods that are destined for export to global customers will fetch a relatively low price.

The Douala-Ndjamena regional rail/road corridor passes through the Far North region of Cameroon and plays a critical role in linking secondary population centers, such as Garoua, Maroua, and Kousséri, to the capital cities Ndjamena and Yaounde, as well as to international markets via Douala. Strong transport activity along the corridor also benefits the communities adjacent to the road, as it provides them with an opportunity to supply goods and services to transport operators. The performance of this corridor is, thus, important for international trade and the prosperity of the LCR and also plays a key role for political, social, and economic integration in the region.

Almost 80 percent of Chad's imports enter the country through the Douala-Ndjamena corridor. The deteriorating security situation and attacks by Boko Haram on the northern segment of the corridor have, therefore, been a very serious concern for transport operators, who have explored the use of alternative transport routes to Ndjamena. In particular, a passage that avoids the Far North of Cameroon and runs on Chadian territory has gained interest and traffic, and the Chadian authorities and their developing partners are considering upgrading and developing the track (World Bank 2018b). Instead of going from Ngaoundere via Garoua and Maroua to Ndjamena, the alternative route would run from Ngaoundere east to Koutéré and then continue north to Moundou and Ndjamena (Map 8.1). Parts of the road still need to be reconstructed or rehabilitated to make this alternative branch capable of handling a substantial increase in traffic, but corresponding preparation and work are in progress.

The new eastern branch of the Douala-Ndjamena corridor would provide transporters with an alternative, more secure route to ship their goods to Ndjamena and thus mitigate the risk of Chad being cut off from international markets by Boko Haram attacks in the Far North of Cameroon. On the other hand, the rerouting would drain traffic from the Ngaoundere-Garaoua-Maroua branch and, hence, deprive the population along the corridor of business opportunities. Moreover, there is significant risk of a hysteresis effect. Even once Boko Haram is defeated and the Far North of Cameroon is safe again, it seems unlikely that all the previous traffic would return to the Ngaoundere-Garaoua-Maroua branch. The emergency-inspired development of the Ngaoundere-Koutéré-Moundou branch could thus lead to further economic depression and isolation of the LCR in the longer term.

Map 8.1: Alternative Routing of the Douala-Ndjamena Corridor



Source: World Bank.
Note: AFD/EIB/EC = African Development Bank, European Investment Bank and European Commission.

8.2 Violent conflict and international trade

The Boko Haram insurgency that started in 2009 has severely affected economic activity in the LCR. Originating in northeast Nigeria, the conflict has spread across borders into Niger, Chad, and Cameroon. Boko Haram has repeatedly launched deadly attacks, including on economic targets such as commercial roads and markets, and has generally created an atmosphere of fear and insecurity. Key livelihood activities, such as fishing and harvesting cash crops, have been disrupted or abandoned because of fear of reprisals from Boko Haram or the state's response to the terrorist group. More than 2.6 million people within the region have been displaced because of the hostilities.

Conflict creates humanitarian tragedy and misery, as well as representing an major impediment to development. Violence and insecurity have been shown to disrupt and slow down economic growth (Blomberg and Hess 2002) and can lead to affected countries falling into a so-called conflict trap if the hostilities are ongoing or repeated (Collier et al. 2003). Trade itself can be either a driver of conflict, by providing rebels with supplies from neighboring countries as well as a potential stream of income from informal taxation, or a force of stability, by generating employment and prosperity that would be put at risk by disruptive violence or fundamental changes in governance.[386]

The response by the authorities to rebel or terrorist violence can also cause trade and economic disruption. Measures such as border closures; restrictions on the production, use, and sales of certain products; or curfews and other constraints to people movement can have a profound effect on economic activity. Such actions might be necessary as emergency responses to rein in and defeat the uprising, but if they stay in place for a long time, substantial damage might be inflicted on the economy. Indeed, the containment measures might turn out to be counterproductive in the longer run if they lead to an impoverished population sympathizing with the rebels, supporting them, and strengthening their ranks with new recruits.

8.2.1 Border closures

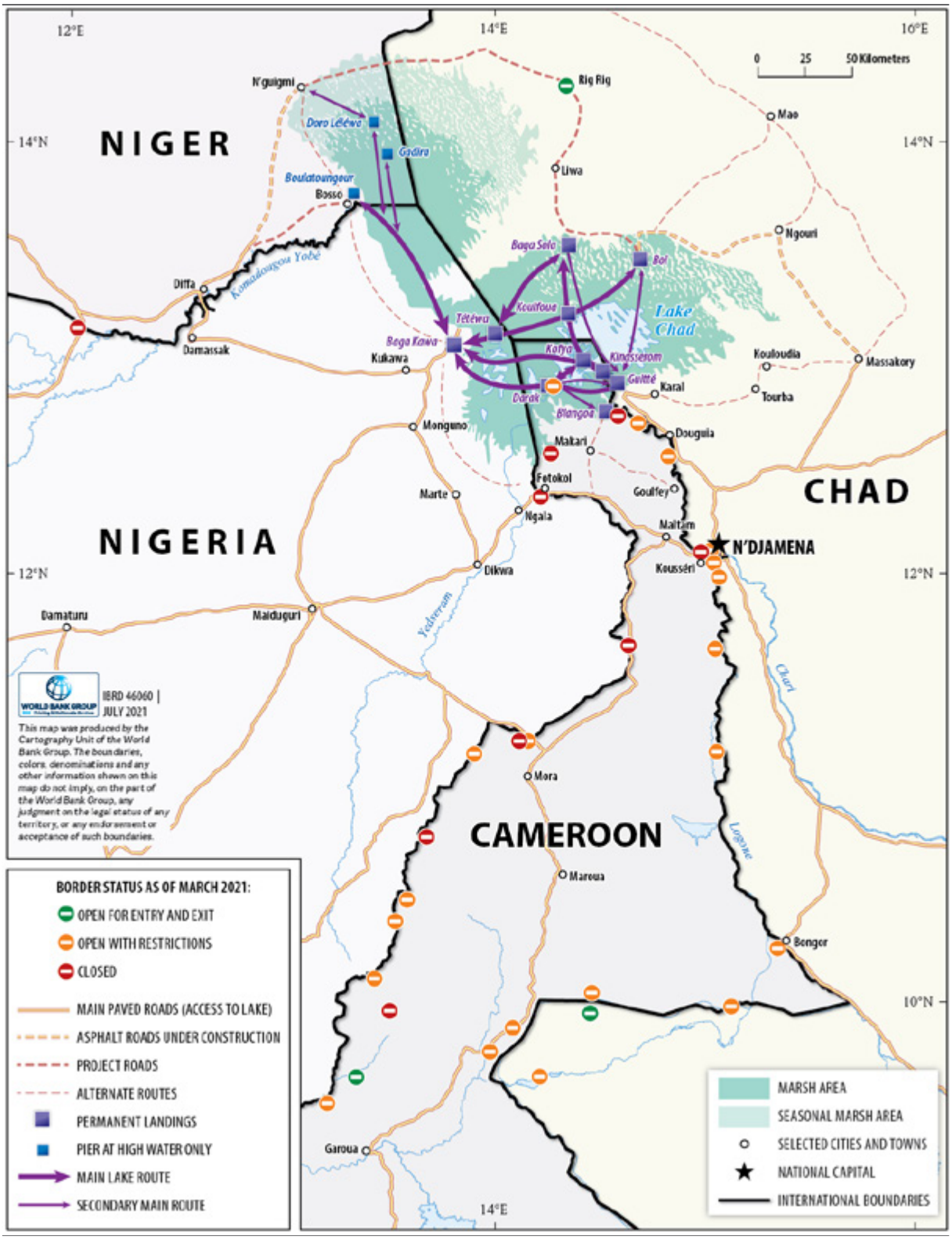
At the beginning of 2012, Nigeria closed its international borders in the northeast part of the country to limit the movement of Boko Haram fighters, disrupt their supplies, and inhibit their ability to levy informal taxes on traders. As the violence subsequently intensified and spread to neighboring countries in the LCR, Cameroon, Chad, and Niger also imposed stricter border controls and closures. The severity of the situation has been further compounded since 2020 by the COVID-19 pandemic, which led to the imposition of additional cross-border travel restrictions and bans.

Data from the International Organization for Migration (Map 8.2) show that as of March 2021, many border crossings in the northeast of Nigeria remain closed (red squares), while almost all other border posts in the LCR are open only for commercial traffic (yellow squares). Very few crossings are described as open for entry and exit (green squares).

Border closures have a severe impact on the local populations. They imply a drastic reduction in demand for transport and other trade-related services, which often provide employment for a sizable share of the men and women of the border communities.

386 In countries with point-sourced export commodities, such as oil or gemstones, there is also the risk that the concentrated export revenues will provide a trigger for the government and rebels to fight over control of the production locations (Calli 2015).

Map 8.2: Border Status in the Lake Chad Region as of March 2021



Source: International Organization for Migration database, March 2021.

Border closures also depress trade volumes and force traders to make costly detours. This means longer transport times, more fuel and vehicle maintenance expenses, and higher payments to clear roadblocks and checkpoints on the longer route. In some cases, there are also higher trade taxes involved. For example, the closure of borders in northeastern Nigeria has shifted trade flows from Lagos and other Nigerian ports that are destined for Chad to pass through Niger. Nigerien customs has collected new transit fees on these trade flows to Chad, and goods have subsequently also been taxed by Chadian customs. In 2016, Niger and Chad signed an agreement to avoid this double taxation (Cantens and Raballand 2017).

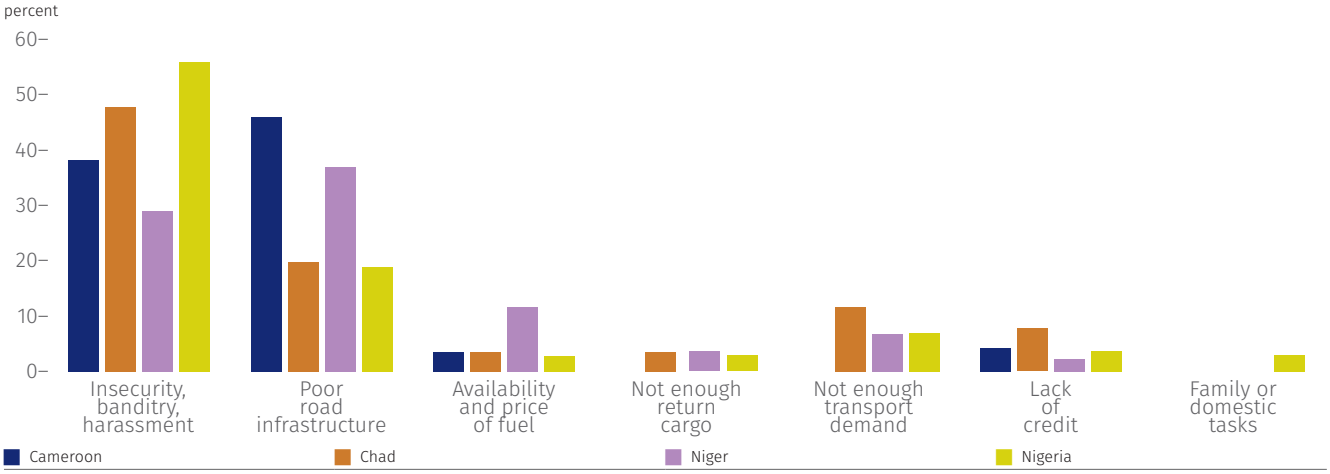
Yet despite the widespread border closures, interviews with local traders in June 2019 suggest that it is still possible to traverse into the neighboring country at supervised border crossings if "facilitation payments" are made. An individual would have to pay US$12.50–14.00 in bribes to cross from Cameroon into Nigeria (Sagagi and Thorburn 2019). For trucks, the unofficial payments were reported to be at least 20 times higher. Hence, it is still possible—but expensive—to cross at closed border stations in the LCR.

8.2.2 Transport impediments

Trade in the LCR is slowed down and taxed by formal or informal checkpoints and roadblocks along transport routes. These controls by the police and military are intended to impede the movement of Boko Haram fighters and their supplies. In addition, bandits and terrorists operate their own informal checkpoints to extract payments from traders and travelers. A survey of 305 transporters in the LCR undertaken on behalf of the World Food Programme in 2016 found that supply routes for cereals in Borno State are subject to a particularly high number of checkpoints (Table 8.2), reflecting the intensity of Boko Haram activity and corresponding countermeasures in this region. Similarly, the total amount of payments demanded is very high in Borno State and also in some other regions, such as Diffa in Niger.

The transporter survey also asked the respondents to identify the main constraints to their trading activity. Insecurity and poor road infrastructure were seen as the main impediments to trade and transport (Figure 8.1). In the Chadian and Nigerian parts of the LCR, insecurity was mentioned more than twice as often as infrastructure as the most serious concern, while in Cameroon and Niger, the poor state of the road network topped complaints about the lack of security.

Figure 8.1: Principal Constraints Faced by Transporters in the LCR



Source: Brunelin and Renk 2016.
Note: LCR = Lake Chad region.

Table 8.2: Transport Impediments on Cereal Supply Routes

	Cameroon	Chad		Niger	Nigeria		
	Extrême-Nord	Lac	Hadjer Lamis	Diffa	Adamawa	Borno	Yobe
Average distance (km) to main cereal market supply	93	50	178	109	34	249	92
Number of formal checkpoints	2	3	8	5	2	16	3
Number of informal checkpoints	5	1	2	2	1	8	3
Total number of checkpoints per 100 km	7.5	8.0	5.6	6.4	8.8	9.6	6.5
Amount of taxes paid by pickup driver (US$)	1	11	11	40	1	3	2
Amount of taxes paid by truck driver (US$)	73	N/A	19	76	1	127	12

Source: Brunelin and Renk 2016.
Note: km = kilometers.

8.2.3 Restrictions on fertilizer use

The authorities in the Lake Chad basin have implemented strict limits on the use and trade of nitrogen fertilizer (N fertilizer) because of fear that it could be used by Boko Haram for bomb-making.[387] In Nigeria, imports of nitrogen fertilizers have been limited to a positive list of "safe" products, and a comprehensive tracing protocol has been put in place to govern the import, manufacture, distribution, and handling of N fertilizer.[388] Similarly, in Niger, farmers in the Diffa region have had to apply for licenses to buy nitrogenous fertilizer, and imports from Nigeria have been prohibited. These restrictions have resulted in higher fertilizer prices and reduced application rates, with adverse consequences for crop yields.

Nitrogen fertilizer can and has been used by terrorist groups to produce improvised explosive devices that were later used in violent attacks. Some fertilizers, such as ammonium nitrate, can be used as explosives in their own right and are, therefore, on the list of banned imports in Nigeria. Others, such as urea, are chemically stable and must be treated with particular chemicals, notably nitric acid, to produce an explosive. This transformation into explosive materials requires advanced education in chemistry and specialized laboratory equipment, which might be difficult for a terrorist group in a field camp to procure and operate. Some observers have therefore argued that it would be more effective and less disruptive for farming if the authorities were to strictly control the import and handling of nitric acid instead of restricting a broad range of fertilizers that are by themselves not dangerous (Argus Consulting Services 2016).

8.2.4 Restrictions on access to farming and fishing locations

The presence of Boko Haram in certain zones and the response by the authorities to militarize large areas has cut off some farmers and fishers from their land or fishing grounds. Farmers in these areas have been reluctant or unable to work their land because of fear of encounters with Boko Haram or fear of being taken by the military to fight Boko Haram. In addition, restrictions

387 Improvised explosive devices pose a significant threat. Bombs and land mines have been injuring or killing people in the LCR and restricting people's access to agricultural land. The Mines Advisory Group reported that between January 2016 and March 2018, 439 casualties resulted from land mines and unexploded bombs in northeastern Nigeria. See Mines Advisory Group website, https://www.maginternational.org/what-we-do/where-we-work/nigeria/.

388 See End User Certificate Portal, "Guideline for Procuring Fertilizer Chemicals," https://euc.nsa.gov.ng/fertilizers.

on certain transport vehicles (for example, motorbikes in Niger) have impeded access to more remote farming locations. As a result, crop production has suffered and output of cash crops for export is down (see, for example, section 3.4 of this paper, "Dried red pepper exports from Diffa").

Similarly, bans on fishing boats, fishing, and fish selling have had a devastating effect on the fishing communities around the lake and on cross-border fish trade. The bans are intended to deprive Boko Haram of escape and supply routes across the lake and to cut the income stream that the terrorists supposedly derive from the fish trade. For the fishers, the ban has meant that they and their families had to look for alternative livelihoods or continue to fish clandestinely and thereby expose themselves to significant security risk or severe sanctions (see, for example, section 3.3, "Smoked fish exports from Diffa").

8.3 Trade relationships

The Lake Chad region has a history of lively cross-border exchanges. Products from agricultural surplus areas supply towns and cities, while manufactured goods are shipped from the south of Nigeria or Cameroon to the agglomerations of Maiduguri and Ndjamena, from which they are distributed to the surrounding areas. Large urban centers and border towns feature important permanent markets, as well as warehouses. The latter make it possible to store surplus merchandise and later deliver it to other localities. Smaller towns typically hold weekly markets.

The transport infrastructure to the south of Lake Chad is better developed than that on the lake's northern shore (Map 8.2). In fact, some cross-border trade of fish and other products used to occur across the lake using pirogues, as this direct link is quicker and cheaper than road transport around the northern shore.

Mutual trust is of fundamental importance in trade relationships, and many trader networks in the LCR are based on regional or ethnic affiliations. Many of these networks among Hausa, Kanouri, Arab, Peul, or Fezzanais extend across borders and facilitate import and export transactions. Research using high-frequency price data found that informal networks along the border between Niger and Nigeria are highly effective in integrating markets (Aker et al. 2014). Common ethnicity was reported to result in lower price dispersion across countries than across regions of differing ethnic composition within countries.

The following sections illustrate the cross-border trade relationships for several commodities in more detail. Some of the value chains are important across the entire region (cereals, fish), while others illustrate sectors that are of significance in individual countries or regions (red pepper in Diffa, Niger; onions in northern Cameroon; cattle in Chad).

8.3.1 Intraregional cereals trade

Nigeria is the origin of most grain supplies in the LCR. Cereals are grown in rural areas throughout Adamawa, Borno, and Yobe States. In addition, substantial supplies come from Kano or even further afar. These supply streams continue, despite the Boko Haram insurgency, but local production has been adversely affected by reduced N fertilizer availability and higher fertilizer prices, restricted access to land in militarized zones, and direct regulation of selected agricultural activities. For example, the cultivation of "tall" crops, such as maize or sorghum, was banned because it was seen as decreasing military visibility and potentially creating hiding grounds for the insurgents.

Table 8.3: Farmer-Reported Typical Harvests before and during Conflict in Borno State

Farmer ID	Crop planted	Typical harvest (2004–08), tons/ha	Typical harvest (2009–13), tons/ha	Percent change
1	Cowpea	1.0	0.3	-70
2		2.0	0.5	-75
1	Maize	2.8	0.4	-86
2		4.8	1.0	-80
3		15.0	2.2	-85
1	Sorghum	0.8	0.0	-100
4		20.0	6.4	-68
3	Rice	3.0	1.5	-50
4	Millet	5.0	1.1	-78

Source: Kimenyi et al. 2014.
Note: ha = hectare.

Anecdotal information from interviews with four farmers in Borno State suggests a major slump in agricultural output. Higher prices and reduced availability of farming inputs has depressed yields by more than 50 percent (Table 8.3). The magnitude of these changes is confirmed in a report by the Center for Strategic and International Studies' Global Food Security

Program, which estimated changes in sorghum, rice, and millet production in Borno State between 2010 and 2015 to amount to, respectively, 82 percent, 67 percent, and 55 percent (CSIS 2020). These findings attest to the damage that the Boko Haram violence and the countermeasures taken by the authorities have inflicted on the agricultural economy.

The Diffa region in Niger traditionally imports substantial amounts of cereals from Nigeria. Before the Boko Haram attacks, the axis Damasack–Diffa was the major trade corridor. However, this route is no longer used because it is no longer safe, and supplies have instead been sourced along the Geidem-Gashua corridor. According to reports by the World Food Programme, these places of origin are providing almost 70 percent of the traditional grains, maize, and cowpeas (*niebe*) found in markets in Diffa (Brunelin and Renk 2016).

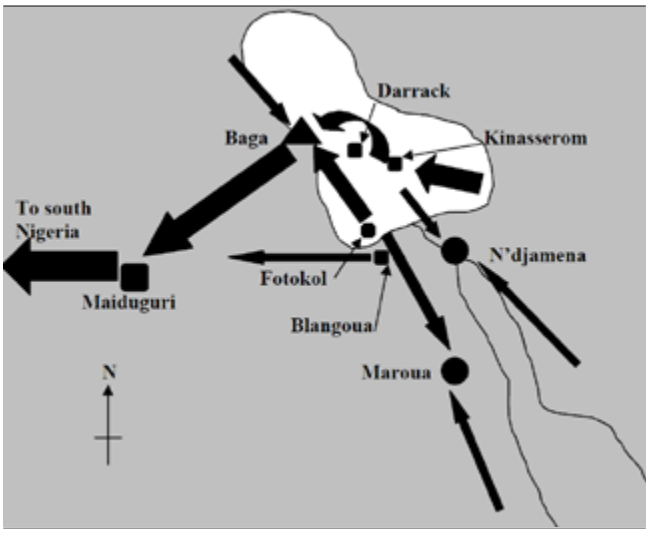
Similarly, the long land border between Nigeria and Cameroon used to see lively cross-border trade, mainly of an informal nature. Estimates put the value of exports from Cameroon to Nigeria of paddy rice, other agricultural products, and soap at US$64 million, while Nigeria exported US$176 million worth of cosmetics, plastics, footwear, and other general merchandise to Cameroon (World Bank 2013). A number of major trade routes link the two countries, several of which connect northeastern Nigeria to the Extreme North Region of Cameroon. These include the corridors from Maiduguri to Kousséri, Maiduguri to Maroua, Banki to Mora, Mubi to Guider, and Jimeta/Yola to Garoua. However, the northernmost of these corridors have become subject to important security risks and are therefore avoided by transporters in favor of the more secure corridors from Mubi to Guider, Jimeta/Yola to Garoua and routes running further south (Sagagi and Thorburn 2019).

In Chad, most cereal supplies for the food deficit region of Hadjer Lamis originate in the Lac region or other domestic surplus regions.

8.3.2 Traditional trade flows for fish

Two types of fish trade exist around and across Lake Chad. The first type is the supply of fresh or processed fish by fishers or merchants to markets in nearby villages and towns for consumption in proximity to the fishing grounds. The second type is the long-distance trade of dried or smoked fish. This second type of trade involves specialized traders and large transport vehicles, and it connects to urban centers within countries or across borders. In particular, large quantities of fish have been shipped through Baga and Maiduguri to major agglomerations in southern Nigeria (Map 8.3), such as Abuja, Onitsha, Enugu, Lagos, and Ibadan. It should be noted that most of these exports are informal and not recorded in official trade statistics.

Map 8.3: Historical Trade Flows for Fish in Lake Chad Region



Source: Neiland and Béné 2004.

In Cameroon, a large share of fish production used to be exported to Nigeria. The main trade routes run from the markets of Fotokol and Blangoua to the market centers at Baga on the western shore of Lake Chad in Nigeria or directly to Maiduguri.

In Chad, major export trade used to occur across the lake. Fish caught in Chadian waters were transported and sold to the island markets of Kinasserom and Darrack,

from which they would continue their journey to Baga in Nigeria.

In Niger, exports of fish caught in Lake Chad or its tributary rivers also run through Baga and Maiduguri in Nigeria.

The entrenchment of Boko Haram on the shores of Lake Chad, large-scale attacks such as the Baga massacre of January 2015, and containment and reprisal actions by the national and joint military forces have fundamentally disrupted the aforementioned traditional trade routes for fish. As a result, cross-border trade volumes have been reduced, and longer, more costly trade corridors are being used.

8.3.3 Smoked fish exports from Diffa

Exports of smoked fish from the Diffa region in Niger to Nigeria used to be of substantial importance. Estimates suggest that until 2014, about 14 percent of the population on the shores of Lake Chad and alongside the Koumadougou River that separates Niger and Nigeria derived their livelihood from fishing, fish smoking, and fish trade (Sissons and Lappartient 2016). The imposition of the state of emergency in the Diffa region in February 2015 and the subsequent surge in Boko Haram attacks have fundamentally disrupted fishing activity and stopped smoked fish exports altogether.

Lake Chad and the Koumadougou River are fertile inland fishing grounds. In the Diffa region, about 15,000 fishers and their families used to make a living from fishing. It is notable that a large number of fishers were foreign citizens. The local chamber of agriculture estimated that only 40 percent of fishers in 2010 were from Niger, while the remaining 60 percent were from Cameroon, Chad, Nigeria, and other countries (Chambre Régionale d'Agriculture de Diffa 2010a).

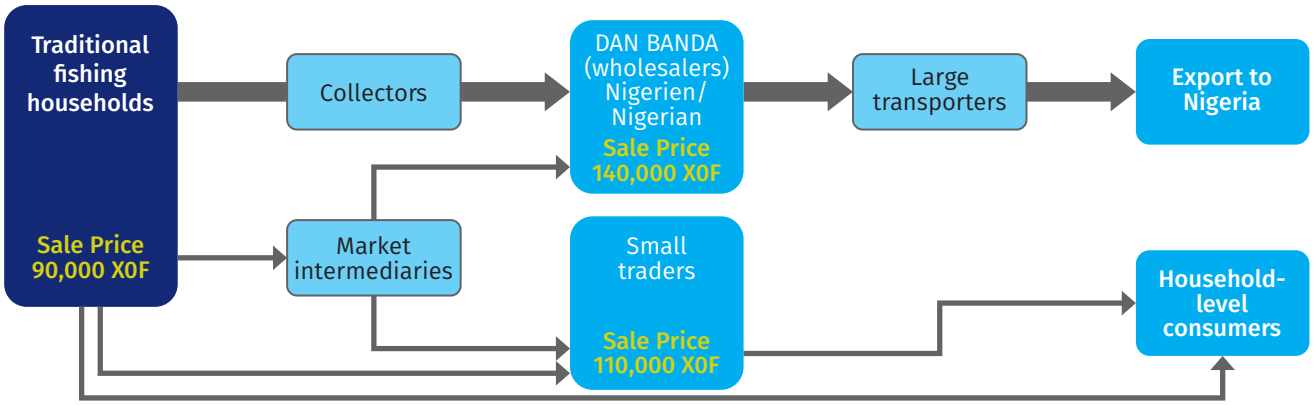
Smoked fish production typically involved the entire family. The men would go out on the lake or river to catch the fish, and the women and children handled the smoking process and local sales. Because of the difficulties of stocking and transporting fresh fish in the climate of the Sahel, not much fish was sold fresh. Instead, the catch was most often immediately smoked in traditional ovens to make it storable. It was then packaged in 50 kilogram boxes for marketing.

A small share of the fish caught used to be sold in local markets for consumption by the local population, but 80–90 percent of all fish caught was exported to consumption centers in Nigeria, notably Maiduguri. For this cross-border trade, fishers would work through specialized intermediaries. Wholesalers would send collection agents into the villages to buy up the fish and transport it to local market centers for consolidation into larger lots and subsequent truck-based export to Nigeria (Figure 8.2). In 2014, the value of fish production in the Diffa region was assessed as CFAF 20 billion or US$34.5 million (Sissons and Lappartient 2016), so if an estimated 85 percent of this production was exported, then the export value amounted to about CFAF 17 billion or US$29.3 million.

Before the imposition of the state of emergency in February 2015, Boko Haram already had an adverse effect on the smoked fish trade in the LCR. The terrorist group occasionally attacked transports on their way to Maiduguri, thereby increasing the risks of such transports and augmenting transport costs. Moreover, Boko Haram forced fishers on the lake shore to make informal payments, thus reducing the profitability of their activity. Yet despite these criminal activities, fish production and trade continued.

In contrast, the declaration of the state of emergency for the Diffa region on February 10, 2015, quickly brought fishing and fish trade to a halt. It entailed a curfew, a prohibition on motorbike transport, a stronger military presence, and more frequent violent attacks from Boko Haram, which was reinforcing its presence in the lake area. Moreover, fishing and fish selling were banned, as these activities were seen as a source of revenue for Boko Haram, and the lakeside population was evacuated inland

Figure 8.2: The Smoked Fish Market Chain in the Diffa Region



Source: Sissons and Lappartient 2016.
Note: XOF = West African CFA franc.

or fled from their villages and camps to avoid encounters with Boko Haram. The border to Nigeria was closed.

The authorities have actively enforced the restrictions. In particular, the military has arrested fish transporters, seized fish transports, and subsequently burned the cargo and vehicles. For example, the regional authorities destroyed 2.7 tons of smoked fish in April 2016 (van Lookeren Campagne and Begum 2017).

As all fishing-related activities became illegal, most actors in the value chain had to look for alternative sources of income, such as petty trade, charcoal production, or firewood and straw collection. Few individuals take the risk of fishing illicitly, and those who do so limit themselves to catching fish at night without boats for sale to local households. Smoked fish exports to Nigeria became marginal. Sissons and Lappartient (2016) report that the income of the remaining, clandestine fishers has dropped by more than 70 percent compared with the revenues they had before the state of emergency.

In March 2019, the authorities lifted the ban on fishing and fish trade. Yet as the supply of credit and inputs that fishers used to get from their wholesalers disappeared, a lot of the fishing equipment has fallen into disrepair. This deterioration of the production base, together with the impoverishment of the fishing population and the disappearance of the network of traders and other intermediaries in the value chain, means that the recovery of smoked fish exports after the fishing ban was lifted is slow. The conflict with Boko Haram has destroyed a lot of physical, institutional, and social capital, and restoration will take time.

8.3.4 Dried red pepper exports from Diffa

Red pepper is an important cash crop in the Diffa region. Oxfam estimates that 80 percent of rural households have been involved with pepper cultivation, processing, and sales (Sissons and Lappartient 2016). Annual production used to amount to 10,000 tons, with a market value of CFAF 8 billion or US$13 million (Chambre Régionale d'Agriculture de Diffa 2010a). About 80 percent of total production, with a value of US$10.4 million, was exported to Nigeria via Damasak and Maiduguri. The imposition of the state of emergency in February 2015 led to a significant reduction in dried red pepper production and trade, as sales and transport of the crop were initially banned and then (from June 2015) restricted to transactions within Niger only. These restrictions were motivated by the presence of Boko Haram along the border between Niger and Nigeria and the fear that the terrorist group used informal taxes on red pepper trade to finance its activities.

Also known as "red gold" because of its high market value, red pepper used to be grown by 5,000 to 6,000 pepper producers in the area that is irrigated by the

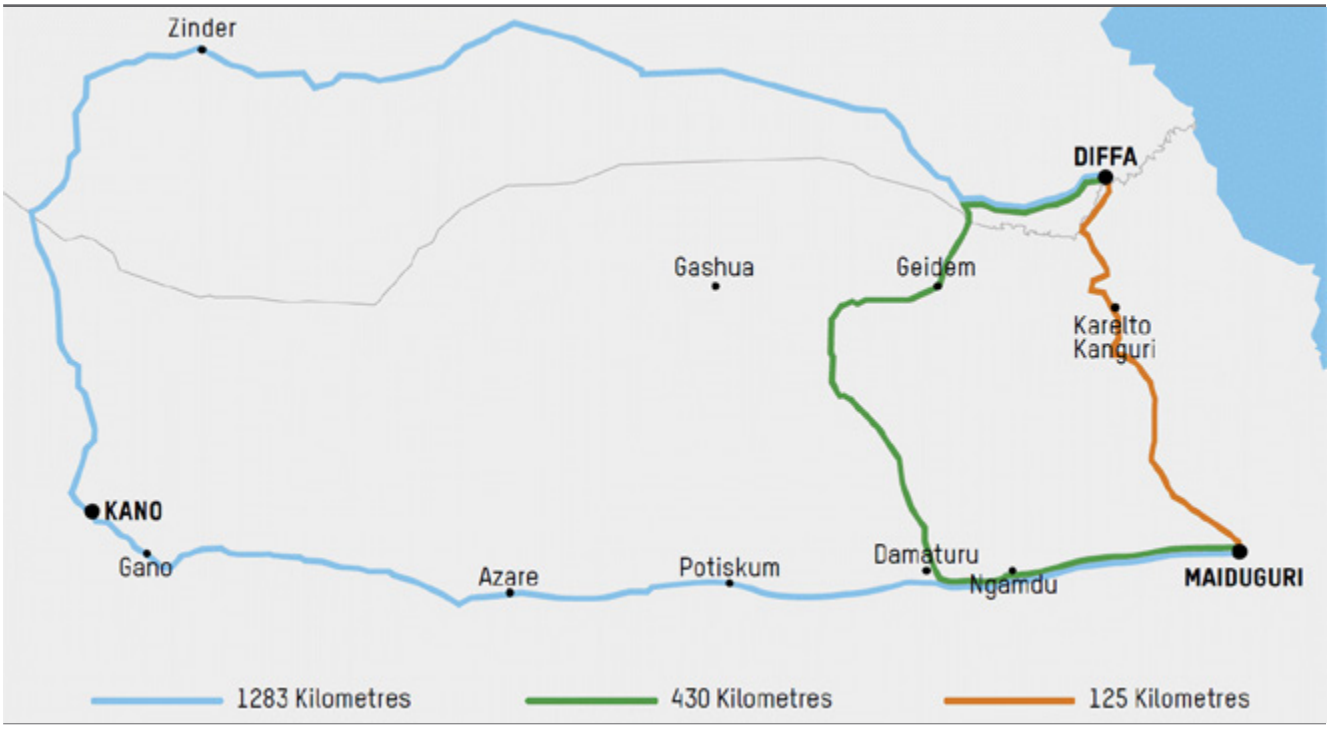
Koumadougou River. At harvest time, the pepper was sun-dried for 15 to 25 days and then packaged in jute bags that typically contain 17 kilograms of product. Intermediaries that are operating at the village level on behalf of pepper traders negotiated the prices with farmers and organized the transport to market centers, where the shipments were sold locally or consolidated onto large trucks for export to Nigeria. Consumers would typically buy the product in powdered form to prepare sauces or to season meat and rice.

The closure of the local border with Nigeria forced traders to ship their product to Nigeria via trade routes that are substantially longer (Map 8.4). Instead of taking a direct route of about 125 km from Diffa to Maiduguri, traders are now diverting their trip through Geidem and Damaturu (430 km) or even pass through Zinder and Kano (almost 1,300 km). The longer route exposes them to extra security risk for themselves and their cargo and significantly augments their transportation costs.

The local border closure also means that farmers can no longer purchase fertilizer to nourish their crops and fuel to operate their irrigation pumps from across the river in Nigeria. Moreover, domestic purchases in Niger of fertilizer and fuel have been restricted for fear that Boko Haram might use nitrogen fertilizer for bomb making and use fuel to propel the vehicles and motorbikes of its fighters. Farmers need a permit to obtain fertilizer and fuel, and allocations are substantially below historical levels of use, so pepper yields have suffered.

Moreover, the militarization of the border zone has meant that many farmers have been unable to access their land. Military forces have established ad hoc camps in the pepper production zone, and regular patrols of the border zone by national and multinational forces limit the possibility for farmers to work their fields. In addition, many farmers have fled their villages because they fear that Boko Haram might attack them. As a result, the cultivated pepper area has dropped markedly.

Map 8.4: Red Pepper Trade Routes from Diffa to Maiduguri



Source: Sissons and Lappartient 2016.

The combination of the restraints on sales and trade of red pepper, the restrictions on fertilizer and fuel use, and the limitations on land access have had a profound effect on the pepper sector. Red pepper output in the Diffa region is estimated to be 50 percent lower than before 2015, and farmers' income from pepper production is as much as 80 percent below the pre-emergency level (Sissons and Lappartient 2016). Also, intermediaries, such as transporters, have been adversely affected by the reduced volumes and increased transaction costs. For example, transporters face a 50 percent drop in their activity volume and income.

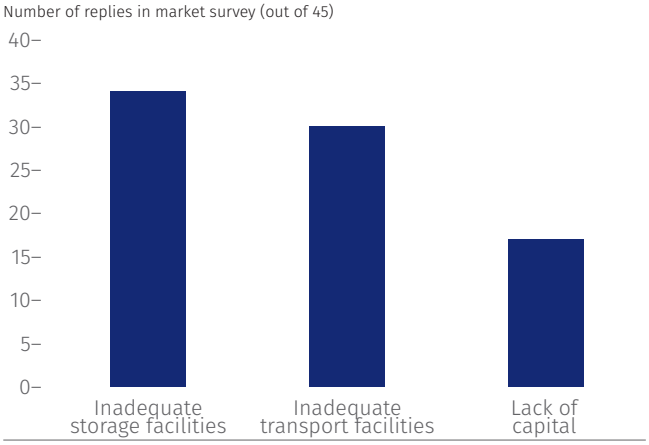
8.3.5 Onion exports from Cameroon

Onion production is an important branch of agriculture in some parts of Cameroon. It is estimated that 85 percent of onion production is concentrated in the North and Far North regions of the country, where it is the most important cash crop (Kamdem, Kamga, and Schreinemachers 2017). As a result of cultural norms, onion production is mostly controlled by male farmers (Kanga et al. 2016).

Parts of the local onion production are sold in nearby markets to local consumers, but a significant share is shipped to consumption centers in the south of Cameroon or exported to Nigeria and Chad from markets such as Kousséri and Amchide. Ndenkah (2013) estimates that total formal and informal exports of onions from Cameroon to Chad amounted to 19,249 tons, at a value of CFAF 3.4 billion. The main market for onions on the Nigerian side of the Nigeria–Cameroon border is Wulgo in Borno State (Magrin and Ngaressem 2014).

In a survey of onion traders in Borno State, the lack of adequate storage facilities and appropriate transport facilities were identified as the most important challenges to onion marketing (Figure 8.3). The lack of security was not mentioned as a primary problem in this survey. However, this absence is consistent with other survey findings on cereal markets in the LCR, where it is the transporters and not the traders who are most seriously affected by and concerned about attacks, theft, and violence (Brunelin and Renk 2016).

Figure 8.3: Constraints to Onion Marketing in Borno State



Source: Sulumbe, Shettima, and John 2015.

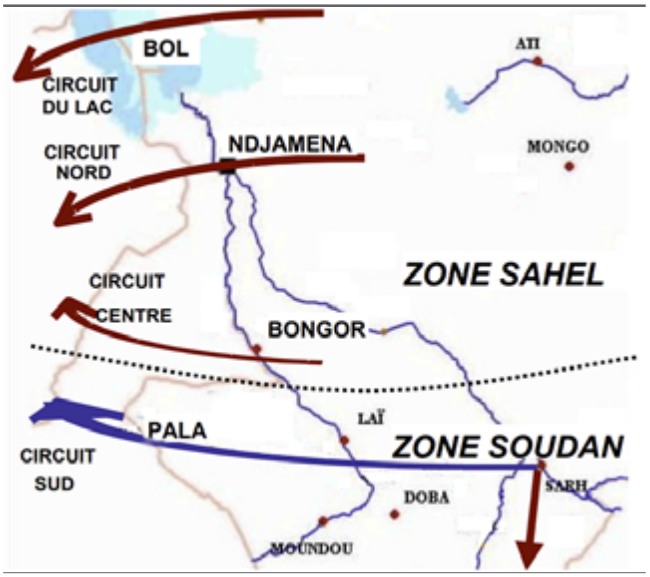
8.3.6 Cattle exports from Chad

Chad is a major exporter of animal products. Because meat requires refrigeration during transport, most trade takes place by transporting live animals. A significant share of Chad's exports is thereby destined for Nigeria and transits through the North or Far North region of Cameroon. Major transshipment points in Cameroon are the cattle markets of Bogo and Adoumri (Engola-Oyep and Herrera 1997).

There are several marketing pathways (Map 8.5). One circuit crosses the Lake Chad region and supplies the Maiduguri market. This export flow is particularly active in the dry season. The so-called northern circuit passes through Ngueli and also joins Maiduguri. It is active year-round and drains export herds from markets located in the center and north of Chad. The center circuit passes through Bongor to reach the Banki market via the Bogo relay market in Cameroon. This pathway brings animals from the center and the south of Chad. In addition, the southern circuit crosses the area of Pala in the province of Mayo-Kebbi Est and leads to the market of Mubi in

Nigeria after crossing Cameroon. It is supplied by flows from the southeast of Chad.

Map 8.5: Circuits of Cattle Exports from Chad



Source: Duteurtre and Kousso 2002.

Live cattle trade is highly organized along ethnic lines. Animals are mainly sold at weekly markets. Transactions rely on the presence of guarantors (*damin*), who are appointed by the traditional chiefs of different groups of nomadic herders and are recognized as such by market authorities. Their role is to welcome the traders of the ethnic group concerned, to house them, to accompany their animals to the market, to put them in contact with buyers, to certify the origin of the animal, and to guarantee the payment of official taxes. The guarantors only intervene in the trade of their own ethnic group: Missirie Arabs, Ouled Rached Arabs, or Peuls. The ethnic networks of traders rely primarily on a relationship of trust, which does not necessarily involve family ties.

A large share of cattle trade is informal. Even if borders are formally closed, herders seem to have little trouble walking their cattle across into their destination country.[389] Estimates put the annual cattle exports from Chad to Nigeria at 520,000 animals in 2000, of which only about 35 percent were declared and captured in official statistics (Duteurtre and Koussou 2002). More recent estimates put the volume of live cattle exports from Chad to Nigeria at 300,000 animals (Koussou and Duteurtre 2013). Although these estimates might need to be treated with care, they suggest a marked slowdown in transit and trade between the pre–Boko Haram period and the period of insurgency. Moreover, the subsequent intensification of the conflict has led to further reductions in trade flows. Data from the customs authority in Yagoua, an important livestock crossing point from Chad into Cameroon and Nigeria, suggests that cattle transit fell from 53,662 animals in 2015 to about 33,000 animals in 2016 and 2017, which corresponds to a reduction by about 39 percent (World Bank 2018a).

In addition, the number of cross-border livestock theft incidents in Cameroon has increased on both the Nigerian and Chadian sides, depressing the usual intensity of cross-border transactions. Estimates indicate that during 2013–18, Boko Haram stole at least 17,000 heads of cattle and thousands of sheep and goats in Cameroon, worth around US$6 million (World Bank 2018a). The stolen animals were then sold in Nigeria to finance the insurgency.

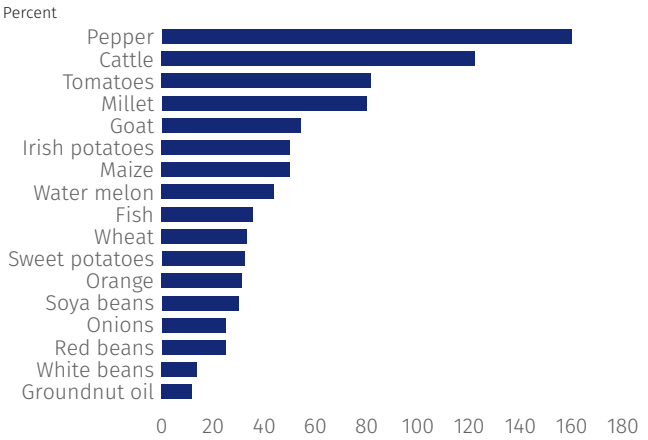
Moreover, there have been a number of violent attacks by Boko Haram on livestock markets. Cattle and other livestock sales involve large cash transactions, which makes traders who carry large amounts of currency an attractive target for bandits. Fear of theft and violence has depressed market activity, in particular for cattle. Markets for smaller ruminants, such as sheep and goats, have been more resilient (Kimenyi et al. 2014).

389 A saying among local transporters is "The ox has no border; the border was erected for human beings." See Canalblog, http://neoindependance.canalblog.com/archives/2014/11/12/30940857.html.

8.4 Market activity and food supplies

The preceding discussion has highlighted the adverse effect that the deterioration of the security situation has had on cross-border trade and trade transactions costs. These higher costs will ultimately have to be borne by consumers in the form of higher prices. Indeed, field surveys undertaken in three major markets in Maiduguri—Monday market, Gomboru market, and Baga market—reveal that some food prices have risen substantially since the start of the Boko Haram uprising (Awodola and Obosh 2015). Vegetables (peppers, tomatoes, Irish potatoes) and livestock products (cattle, goats) are the products that showed the largest price increases in percentage terms (Figure 8.4).

Figure 8.4: Increase in Food Prices in Maiduguri Markets, Pre–Boko Haram Uprising to December 2013



Source: Awodola and Oboshi 2015.

Similarly, analysis by the World Food Programme (2016) showed substantial food price inflation due to insecurity and increased transport costs. Staple food prices in the Nigeria and Niger parts of the LCR were found to be 50 to 100 percent higher than the previous five-year average. Moreover, in 2017, prices of staple cereals in the northeastern Nigeria were 70–124 percent higher than those in the previous year (George, Adelaja,and Weatherspoon, 2019).

8.4.1 Market activity

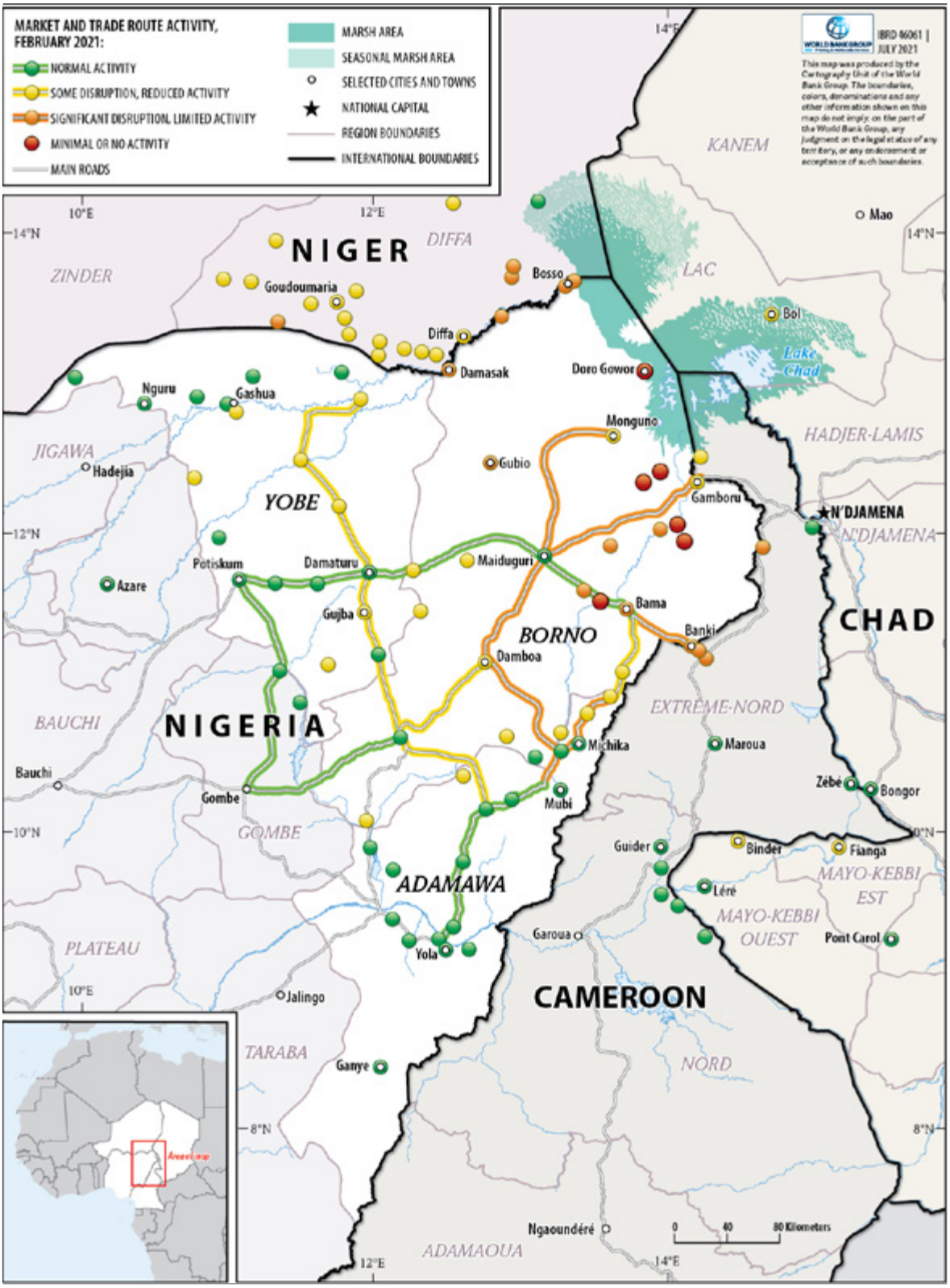
The activity in many markets in the LCR remains below the level of the pre–Boko Haram period. Most markets in Nigeria east of Maiduguri faced significant disruption or had completely ceased to function as of February 2021 (Map 8.6). Also, all markets in the Diffa region of Niger showed significant disruption or reduced activity.

Map 8.6 also shows that the disruption of economic and trade activity is not uniform across the LCR. It is the area in Borno State to the east of Maiduguri that faces the most severe economic depression, as does the Diffa region in Niger (to a lesser extent). Conversely, the Far North of Cameroon and the Adamawa Region in Nigeria are (again) operating at or near normal level.

8.4.2 World Food Programme operations

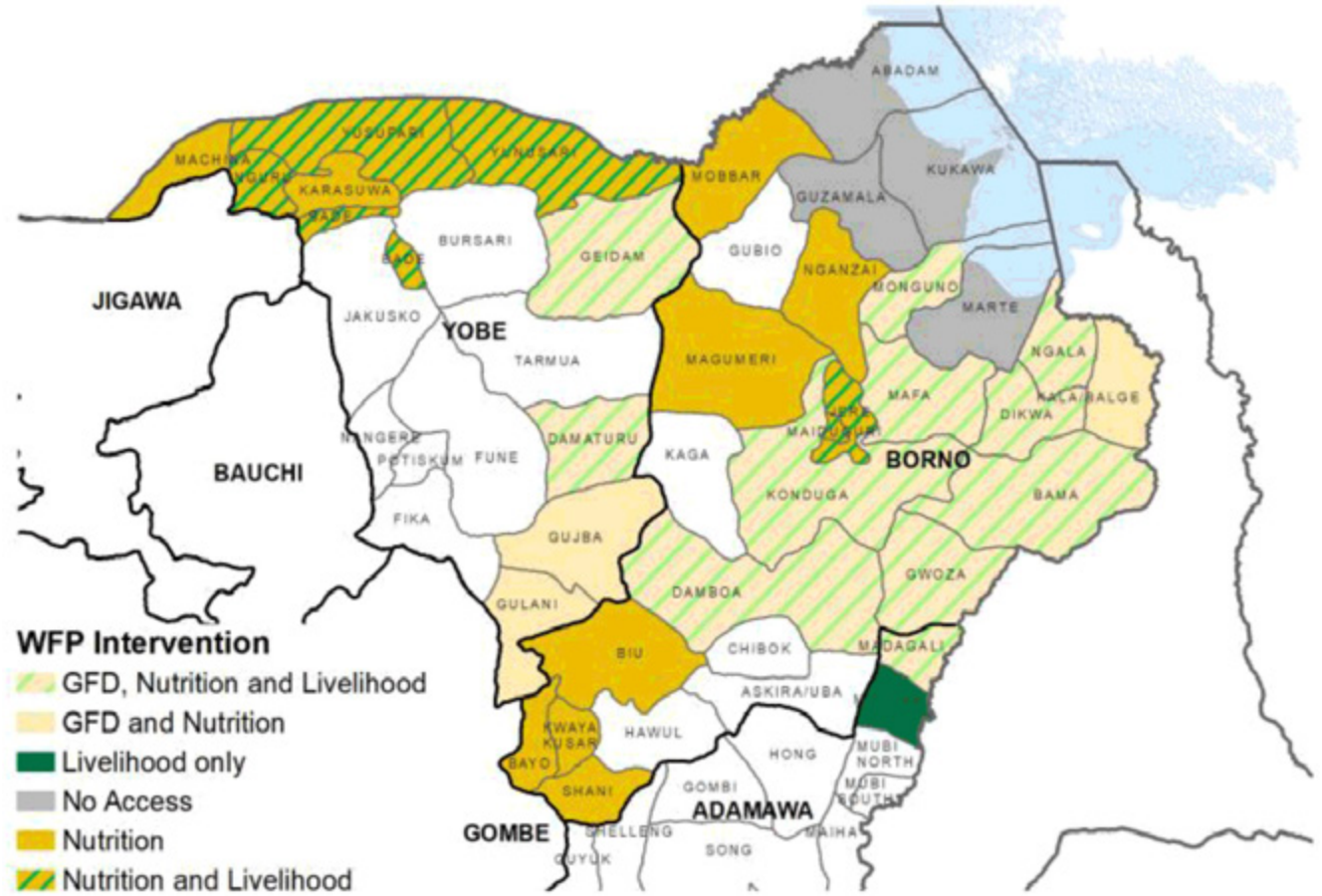
The areas within the LCR where the market and trade activities are most depressed are also the areas where the food security situation is the most critical. The World Food Programme (WFP) has relief operations in all four countries of the LCR and has been providing food, nutrition, and livelihood aid to displaced communities or otherwise severely affected parts of the population. WFP tailors its operations to the local requirements and tries to supply relief aid to all areas within LCR that are in need, except for those zones where the insecurity is too high. For example, in Borno State in northeastern Nigeria, WFP has interventions throughout the state, except for a few districts close to Lake Chad (Map 8.7). In October 2020, WFP and other food security sector partners supported 3.9 million people with food security interventions in Borno, Adamawa, and Yobe States, including 1.7 million provided with emergency food assistance and 2.2 million with support for agricultural livelihoods (WFP 2020).

Map 8.6: Market and Trade Route Activity, February 2021



Source: FEWS NET, February 2021.

Map 8.7: World Food Programme Operational Presence in Northeast Nigeria, January 2021



Source: WFP 2020.
Note: GFD = General Food Distribution; WFP = World Food Programme.

For its emergency food assistance, WFP uses both in-kind food and cash-based transfers. The latter are disbursed as electronic vouchers or mobile money. In 2016, WFP undertook an assessment throughout the LCR to determine the potential for private sector traders to quickly respond to increased demand (Brunelin and Renk 2016). A high-response capacity makes cash transfer programs effective without disrupting local markets to a significant extent. The survey found that in northeastern Nigeria and the Diffa region in Niger, traders estimated to have the capacity to respond quickly to a 100 percent increase in demand. In contrast, in the Far North region of Cameroon and in the Lac region of Chad, almost 40 percent of traders reported that they would not be able to meet a potential increase in demand by 100 percent in less than a week. In these regions, any cash-based transfer assistance might need to be particularly carefully dosed and phased in to avoid strong price hikes that would adversely affect consumers.

8.5 Conclusions and recommendations

The preceding discussion illustrated the adverse effect that increased insecurity in the LCR has had on cross-border trade. Reduced trade flows and higher transaction costs are translating in higher prices for consumers in a region that was already one of the poorest in Africa before the Boko Haram conflict, while the region faces other challenges such as remoteness, environmental degradation, and climate change. Part of the economic damage can be directly connected to terrorist violence, but another part is related to counteractions by the national and regional authorities to contain and eradicate Boko Haram. To counter the ongoing threat and respond to the immediate and longer-term needs of the population, regional authorities need to look beyond security cooperation and move to more significant civilian components for economic development and regional integration. In this context, policy makers in national and regional administration and their development partners might want to consider the following issues as part of a strategy to improve trade and help restore long-standing economic linkages.

8.5.1 Information

Before listing desirable policy direction that Lake Chad countries could investigate, the paucity of reliable and comprehensive information about trade flows in the area must be underscored. Without good trade data, it is difficult to form a picture of one of the key drivers of the economy in the region and an economic dimension that is core to understanding the crisis and its developments. Therefore, a first issue to consider is how to improve economic intelligence of cross-border flows. The following are some recommendations:

- Consider digitizing and using available quantitative and qualitive information from all border agencies (customs) in the region to draw a more precise picture of trade flows and transport conditions along key corridors.
- Investigate additional means to collect high-frequency economic data on cross-border economic activities—such as price data, surveys of border flows, and so forth—in cooperation with other donors and to learn from prior experience in the region (for example, the Permanent Interstate Committee for Drought Control in the Sahel and and Famine Early Warning Systems Network [FEWS NET] surveys).
- Promote the digitization of public data and information, such as farmer registries, to gain knowledge of who is producing and selling which crops.
- Support the collection of information on economic activity and trade to provide policy makers with a better information base. In addition to the compilation of more comprehensive and consistent market price data as is currently available from FEWS NET and WFP, data on traded quantities in markets and the sources of supplies could be collected and monitored.

8.5.2 Trade facilitation

The following are some short-term measures for mitigating the costs of conflict:

- Consider encouraging trade through trader groups or associations and provide military escorts, if necessary, for convoys along key trade corridors to relaunch cross-border trade.
- Collect information on illegal checkpoints and other blockages; trade and share this information across relevant agencies to improve enforcement and to identify mitigating strategies that improve the performance of regional value chains where possible.
- Strengthen the capability of customs agencies to detect illicit trade while facilitating commercial transactions. Equip customs agencies with more modern equipment and intelligence techniques for improved surveillance

and better targeting of risk. Interconnect customs agencies regionally to improve exchange of data and information.

- Ensure that traditional border agencies (instead of security forces) retain in control of border crossings; clarify the roles of border agencies; and minimize the presence of multiple agencies to avoid rent seeking.
- Arrange regular meetings between border agencies in neighboring countries to coordinate security issues, address common challenges, and monitor progress on trade facilitation.

The following are some long-term measures for rebuilding for growth:

- Strengthen and consolidate the provision of border agency services, such as veterinary inspection services, at key border crossings to provide better service quality for traders. Use border crossings as a place to build out and restore the provisioning of government services.
- As security considerations allow, reconstruct damaged infrastructure and markets that are instrumental for relaunching regional trade. Maximize the returns from investments in connective infrastructure (both between and within countries) by coordinating with regional partners.
- Because the new branch through Chad would likely have adverse effects on the prosperity of the LCR in the longer term, critically assess the effects of the planned rerouting of the Douala-Ndjamena corridor and identify mitigating measures where possible.
- Implement AfCFTA commitments and create a cooperation framework to further facilitate trade at borders between ECOWAS and CEMAC members (for example, by allowing visa-free movement of persons and providing an exemption for trade in agricultural and livestock products, as well as for handicraft, from the requirement to be accompanied by a certificate of origin). These measures are already part of the ECOWAS Trade Liberalization Scheme and could possibly be applied at ECOWAS–CEMAC borders on a reciprocal basis.
- Simplify measures at the border for small-scale traders and invest in infrastructure tailored to the needs of small traders.
- Improve the performance of long-distance trade corridors, notably with respect to trade procedures, reduction of harassment, and infrastructure quality.

8.5.3 Other policy issues

The following are some short-term measures for mitigating the impact of conflict:

- Regularly assess the effectiveness and efficiency of economic and trade measures intended to counter Boko Haram, as these affect the livelihoods of export producers and traders:
  - Consider ways to allow gradual and safe access to parts of the lake to renew fishing and fish trading.
  - Reevaluate restrictions on movement, access to farmland, and tall crops to balance the need to contain and suppress Boko Haram with the desirability to restart the local economy.
  - Critically evaluate and manage the risk that agricultural inputs, such as N fertilizer and fuel, pose as potential weapons, with a view of improving farmers' access to these inputs. Examples of possible risk management approaches include trusted trader programs that certify the intermediaries who can trade in particular products.
- Provide support for communities that have been deprived of their traditional export production and trade livelihoods, so that they remain stable and do not offer recruitment potential for Boko Haram.
- Promote the use of solar-powered irrigation pumps to overcome fuel restrictions and shortages.
- Advance the application of digital agriculture innovations, such as mobile money or animal tracing, to reduce the risk of theft.

The following are some long-term measures for mitigating the impact of conflict:

- Provide additional public services close to borders or in cities and markets nearby to build trust in public authority.
- Target support for specific value chains to improve key sources of livelihood in the region. One possible way could be to approach this regionally and thus focus on mutually beneficial value chains.

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Le Pecheur de Kotoko (The Fisherman from Kotoko)
by Abacar Abali Liman (Cameroon)

Ornaments
by Maryam Umar Maigida (Nigeria)

Sultanate in breakdown
by Alichina Allakaye (Niger)

The Tears of a Lake
by Djitara Tendjibaye (Chad)

People forge ideas, people mold dreams, and people create art.
To connect local artists to a broader audience, the cover of this report
features art from the Lake Chad region.

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