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Growing a Developing City

A Computable Spatial General Equilibrium Model Applied to Dhaka

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Abstract

As one of world's fastest growing cities, Dhaka faces acute challenges in housing its growing population and developing a more productive economy. Central to this is the scarcity of high-quality urban land. Yet a vast tract of land near the heart of the city, East Dhaka, currently remains predominantly agricultural and undeveloped as a consequence of flooding. This paper uses a computable spatial general equilibrium model that captures the economic geography of the city, to estimate the economic returns of coordinated action to develop this land. The model captures different productive sectors, household skill levels, and types of housing. Firms and residents choose their location within the city given the transport network and land availability, generating a pattern of commercial and residential land-use. The paper estimates the incremental impacts on income, employment and population of an embankment and other flood protection measures to protect this land, as well as from improvement in transport infrastructure and targeted support for economic development in East Dhaka.

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1. Introduction

Dhaka, one of the world's fastest growing megacities, is projected to grow from its current population of around 14 million to nearly 25 million by 2035. Already there is intense strain on land, transport and other city infrastructure, yet there is also a substantial area of land near the city center that is largely unutilized - East Dhaka, a flood prone expanse of 107km^2. Alternative policies for the development of this area have been studied by the World Bank and are outlined and reported in Bird et al. (2018). This background paper to that report explores the possible economic effects of policies that enable an orderly development of this area, principally by placing an embankment and related flood protection measures around East Dhaka, and improving transport links to and through the area. It also investigates the implications of policy to facilitate the development of new service sector activities in the area, in which case the area's potential has been compared with that of the Pudong district of Shanghai in the 1990s.

The development of such a large area poses numerous questions for the future of the city. What will be the impact of the development on the total population, employment and income of the city? How will other areas of Dhaka be affected by such a development? What will be the impact on different types of economic activity and on workers with different skill levels? It also opens questions on how best to maximize the potential benefits from the embankment: what additional returns arise from developing the city's transport infrastructure at the same time? Can complementary policies that aid cluster formation further enhance the impact of the embankment on the city's output and employment?

To explore these issues, a novel urban computable equilibrium model is developed. There are several key features of the model. First, it is founded in micro-economics; the behavior of households and firms, including their location choices, and their interaction through markets for goods and services, labor and land is directly modeled. Second, the model is highly spatially disaggregate, containing 266 distinct areas, the 'unions' of Dhaka, together with detailed knowledge of economic and residential activity in each and the transport network linking them. Third, the model covers three distinct types of productive activity, two labor-skill levels, and explicitly models housing choice. These distinctions enable us to capture developing country features of a large 'non-tradable-services' sector that corresponds approximately to informal employment. Fourth, we capture the distinction between modern, potentially multi-storey, housing and traditional low-quality housing with two different building technologies, 'modern' increasing capacity by building tall, and 'traditional' where urban density can be increased by 'crowding'. The model is fitted to data on Dhaka and then used to simulate the effect on Dhaka as a whole of alternative development strategies for land in East Dhaka.

In containing multiple sectors and skill levels, the model used draws on an older computable general equilibrium (CGE) tradition. It is important to have these features, particularly in a developing country city, precisely because of the wide range of skills contained in the labor force and the extreme heterogeneity of productive activities, including the high share of the labor force in informal activity. The developing country context also requires that we capture informal sector housing – slums – which we do with the distinction between modern and traditional sectors. They use different building technologies, one expensive and the other cheaper and delivering lower amenity value per unit land area.

The literature on quantitative spatial models has grown substantially in recent years, as summarized in the Redding and Rossi-Hansberg 2017. Most of this work has focused on developed countries, including in Berlin where Ahlfeldt et al. 2015 use the shock of the Berlin wall to examine the impacts of connectivity within a city on urban structure and production. Monte et al. 2015 use a related approach to quantify the benefits from a reduction in commuting costs across cities in the United States. Papers focused on developing countries are more limited however, mainly as a result of data limitations. The model in this paper develops a model set out in Bird and Venables (2019) on Kampala, Uganda, which uses a CGE approach to analyzing the impact of land tenure on the city, and considering the potential welfare impacts of land reform.

Our core results take a benchmark data set of Dhaka in 2035. This data set is based on detailed spatial data for the period 2010-2011 (Li et al. 2016), combined with projections (supplied by the World Bank) of aggregate variables to 2035, knowledge of planned transport improvements, and supplemented by using the model to fill in projections of disaggregate detail. Some economic activity currently exists in East Dhaka, and this is projected to increase over time due to private infilling of land to create low-quality but developable areas. We refer to this as scenario A, or Business as Usual. Given this benchmark we then simulate the effect of increasing the quantity and quality of available land in East Dhaka following the construction of an embankment and related flood protection measures (Bird et al. 2018). The assumed changes are: Scenario B: Reduction in the share of land that floods according to estimates from the Institute of Water Modelling (IWM) (Zaman 2014). This increases the total amount of land developable in East Dhaka by over 50%, from 66km^2 to 102 km^2. We assume that the quality of developable land in East Dhaka rises, as it is no longer infilled land but instead is land protected from flooding by the presence of the embankment. The quality is then assumed to match the median levels of land productivity for firms and amenity for households of Central Dhaka. Scenario C: We modify the transport network to include proposed investments in road and Mass Rapid Transit (MRT) infrastructure, targeted at East Dhaka (Bird et al. 2018). Scenario D: we reduce the costs of doing business for tradable-services firms in East Dhaka, to encourage the formation of new clusters in this area, while boosting further the amenities provided for residents.

We analyze scenario B, our core policy experiment, under a series of increasingly less restrictive assumptions about what changes in the city. Initially we suppose that the structure and location of productive and residential activity changes, but the overall city population remains constant at its 2035 projected level. In East Dhaka the residential population rises nearly threefold, attracted by the increased land availability and the lower risk of flooding, increasing the population density from 14,560 to 40,070 people per km^2, closer to levels seen in Central Dhaka where the base population density is 64,960 people per km^2. There is little change in the share living in traditional housing. The number of jobs in East Dhaka, a measure of economic activity, grows threefold from 454,000 to 1,453,000. By far the majority of this increase in employment is from the manufacturing sector, with some extra jobs in non-tradable-services. In part, this is at the expense of the rest of the city, which experiences a decrease in population density and employment. However, the more efficient location of firms and households nearer the heart of the city leads to aggregate gains, with total wage income rising by 3.2% and total rents by 2%. This increase in output is felt by both the high and low skilled workers living in the city who see an increase in their real incomes per capita of 4.7% and 4.3% respectively. Gross value added (GVA) citywide increases by 3%.

We then allow for a fuller response, with two further margins of change. One is to allow overall city population to change in response to the increase in household real income; with an estimated population growth of 5.9%, this alone leads to the GVA gains from the embankment rising to 9.7%, and real per capita incomes rising by 5%. The other is to add productivity spillovers between firms in the tradable-services sector, capturing the extra benefits that firms reap from being in close proximity to others. Together these further adjustments amplify the impact of the policy change, and total citywide GVA now rises by 10.3%. This is attributable to a larger increase in both manufacturing and non-tradable-services employment in East Dhaka, with the former rising from 111,000 jobs to 1,031,000 jobs, as well as a 6.2% increase in total city population. While the number of jobs and the population in East Dhaka increase as before, this is no longer just a relocation of activity from the rest of the city. The high-skilled, who are more likely to be employed in manufacturing or tradable-services, experience a rise in real incomes of 5.4% per capita whereas the low-skilled experience 4.9% real income per capita gains.

Scenario C models extra transport improvements in addition to the embankment, with the broad effect of nearly doubling the GVA increase to 21.8% compared to 10.3% in Scenario B. East Dhaka has better access to the rest of the city, and the population and employment opportunities increase in this area by a greater degree as a result. The population density rises to 45,800 people per km^2 with a similar share in modern housing as in Scenario B. Additionally, the areas to the east and south of East Dhaka are now better connected to the rest of the city, and we observe an increase in the population density of this area, particularly of low-skilled residents who can use the improved transport system to access central jobs. While Scenario B led to a slight decrease in population density in the historic center of the city, from 64,960 to 59,290 people per km^2, in Scenario C this falls further to 57,100 people per km^2, reducing the congestion pressures in the heart of the city despite the increased overall city population. As manufacturing firms have also moved into East Dhaka, this has reduced pressure on land in the historic CBD, allowing the size of the tradable-services sector to grow here. In total, the real income per capita rises by 10.5% for high-skilled residents, and 9.6% for low skilled residents.

Finally, in Scenario D, we consider additional measures to improve amenity provision in East Dhaka and thereby encourage modern housing, and to promote the development of the tradable-services sector (including finance and business services) in the area. Boosting the amenity levels for modern housing in East Dhaka to the 80th percentile of those observed in central Dhaka promotes the development of modern multi-storey apartment blocks, and we observe an increase in the population density in East Dhaka to 56,000 people per km^2, further reducing the pressures on the old city. We simulate a range of cost reduction measures targeted on tradable-services in a geographically concentrated area in East Dhaka. Tradable-services employment increases in response to these measures, relocating slowly into East Dhaka and away from the historic center. When the costs of doing business for tradable-services in one small union are reduced to match those of the best existing location in central Dhaka, tradable-services make up 8.6% of East Dhaka's employment, a level similar to the citywide shares. Reducing the cost of doing business by a further 20% initiates a substantial relocation and growth of the tradable service sector, as these services come to make up 43.1% of East Dhaka's employment. The size of this impact depends on both the size of the reduction in business costs that the city is able to achieve, the area that this happens in, and the scale of agglomeration economies in the sector. When tradable-services agglomerate more strongly, the initial clusters near the historic center are harder to move into the East. However, with large enough improvements in business costs in a targeted area of East Dhaka, tradable-services will relocate and form a new cluster which increases the total tradable-services output across the whole city.

The following section of the paper outlines the model, the data, and the calibration process. Full details are given in the appendix. Section 3 discusses the projection from 2011 to 2035, and section 4 presents our main results. Section 5 concludes.

2. Model, data and calibration:

2.1 Model outline:

The model is specified in full in the appendix, and here we describe its key features. The model divides Dhaka into 266 geographical units, corresponding to the 'unions' of the city, each of which can contain residential and productive activity. We have data on productive activity and residential occupation in each of these unions, and on transport links between them.

The economic decision-takers in the model are illustrated in the rectangles in Figure 1, and markets are given in the ovals. Arrows represent flows of goods or services. The production side of the economy is represented by firms that use labor, land, and intermediate goods and services to produce goods and services. Firms are grouped into three sectors, manufacturing, tradable-services and non-tradable-services. Each of these is monopolistically competitive, and they differ according to skill requirements, use of land and intermediate inputs, costs of transporting output, and their propensity to agglomerate. The largest sector is non-tradable-services, intensive in unskilled labor, serving the local market, and including both formal and informal sector activity.[1] Output of the other two sectors is 'tradable', meaning that it is sold both within the city and outside ('exported'). These sectors differ in terms of their inputs, with manufacturing the most land-intensive of the sectors, and tradable-services more intensive in

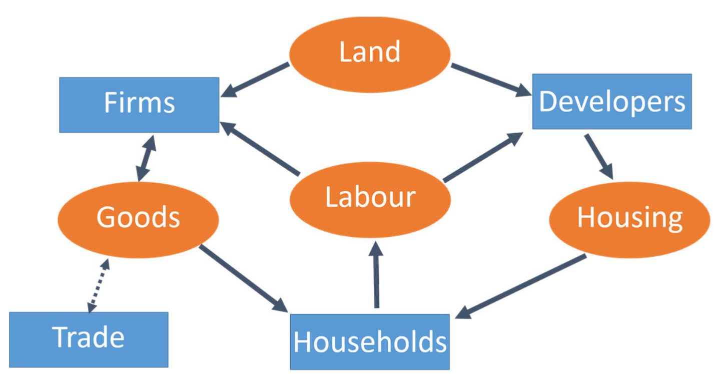
[1] We continue to use the word 'firms' even though much of this sector is unincorporated.

high-skilled labor. All sectors have constant elasticity of substitution (CES) technologies using labor of two skill levels, land, and intermediate goods and services, some of which come from outside the city ('imported')[2], the remainder being composites of goods produced in the city. Firms in each sector choose how much to produce and also, critically, where to locate in the city, this depending on land rents, access to consumers, and access to workers and suppliers of intermediate inputs.

There are two types of households, differentiated by skill level. They supply labor and demand housing, goods and services. Their choices include where to live, where to work, and what sort of housing to occupy. Thus, each household's discrete choice of place of residence and place of work is endogenous, depending on prices (that of land and housing in particular) and commuting costs.

Housing is supplied by 'developers', and to capture heterogeneity of the housing stock we assume two building technologies. One, which we call 'modern', can achieve density (higher floor-space per unit land area) by building tall; this incurs increasing marginal cost, but does not reduce the quality of accommodation. The other, which we call 'traditional', uses materials with poor load-bearing properties so is constrained in its ability to build tall. It can achieve density, but does so by crowding, i.e. reducing space between buildings; more floor-space per unit land area can be produced at constant marginal cost, but its value is reduced as amenity declines with crowding.

Figure 1: Agents and Markets



Spatial connectivity enters the model in three distinct ways. First, workers travel between place of residence and place of work, this being more costly (destroying more utility) the further the journey and the worse the roads along which they travel; it also depends on transport mode (motorized or walking), the choice of which depends on income.[3] Second, goods and services

[2] Food enters the model as an 'imported' input to retail, which is part of non-traded services.

[3] In the application in this paper, for simplification, high-skilled workers have access to motorized

have to be delivered from firms to customers, the costs of which (incurred in 'iceberg' form as lost units of output) vary across sectors according to the tradability of their output within the city and externally. These costs apply to goods used for final consumption and to intermediate goods. The combination of intermediate goods linkages between firms and transport costs creates a force for clustering of activity.[4]

Third, in some variants of the model we allow a further agglomeration force to operate in the tradable-services sector, taking the form of localization economies, i.e. positive productivity spillovers between firms in the sector, the strength of which depends on their proximity to each other. Formally, productivity in tradable-services is an iso-elastic function of the sum of employment in firms in the sector, weighted by negative exponential distance between firms (see appendix equation A6). The distance weights take the form of an exponential spatial decay such that, for example, employment 15 minutes driving time has 0.74 times the impact of employment in same location, employment half an hour away has 0.55 times the impact, and employment at the very opposite end of the city (across the greatest span) has just 0.01 times the impact of employment in the same location. The elasticity of productivity with respect to this weighted mass of employment varies across sectors. In our base case the elasticity is takes value 1.5%, and in section 4 of the paper we explore the effects of varying the magnitude of this elasticity between 0 and 3%.

Firms, households, and developers interact through markets for goods and services, land, labor and housing. Each market operates in each of the spatial units in the city (the unions), so prices and wages are location specific. For goods and services, the variation of prices within the city is small (bounded by transport costs), as it is for labor (bounded by commuting costs). The variation is much larger for land and hence also housing, as the model creates large center to edge variation in land rents. The city also trades goods and services with the outside world, and the equilibrium solves for prices such that supply equals demand in each of these markets, and in each place.

Within this structure, the supply of land is exogenous, although its use (commercial by sector and residential by type, modern or traditional) is endogenous. The allocation of land between competing uses is determined by bid-rents capturing the demand from different sectors of production and types of residential use. The economic use of land in the city varies at two margins, intensive and extensive. Within the city the intensity of land-use can change, e.g. building taller or crowding. And at the city-edge urban use competes with agriculture, some unions containing both in proportions that change as the city grows. Our experiment is to change the supply of land in East Dhaka, as we describe in more detail below. As regards the total urban population, we look at both cases of 'closed' and 'open' cities, the former where

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transport, whereas low-skilled workers commute on foot or public transport. Under the 2035 scenario with transport improvements, the building of an MRT means pedestrians can now also travel along high speed, fixed location, bus routes. High-skilled workers can also use these routes if it lowers their transport times.

[4] This structure of input-output linkages between firms creates a benefit of co-location, as in Fujita et al. (1999).

population is fixed and the latter where urban population expands in response to an increase in urban-rural real income differentials.[5]

2.2 Data:

In this section we outline the data used in calibration; the data is described more fully in the appendix and draws heavily on the World Bank's Spatial Database for South Asia (Li et al. 2016). We start with a sketch of the economic geography of the city.

The geography of Dhaka

The 2010 population of Dhaka is 14.9 million, and its residential density is among the highest in the world. This is illustrated in Figure 2 with residential density peaking in the old city area at around 41,000 per km^2. Employment density is illustrated in Figure 3, with a peak at 135,000 people per km^2. This peak is largely concentrated with service firms, particularly retail. A further large mass of employment spreading to the northwest of the city is the hub of the garment industry.

The city lies in the lower reaches of the Ganges delta and is low-lying, with average elevation of 4m above sea level; wide areas of the city are prone to flooding. To the west the city is bounded by a dike but the eastern side remains largely unprotected. Figure 2 and Figure 3 indicate clearly the area of East Dhaka that is under-developed due to the flood risk, an area of over 100km^2, or over 7% of the total city, yet located very near the CBD. The project analyzed in this paper is the construction of a dike on the eastern side of this area. More detailed maps, which show the employment density broken down by sector, and the population density by housing type and educational level, are given in the appendix.

Figure 2 Residential Density

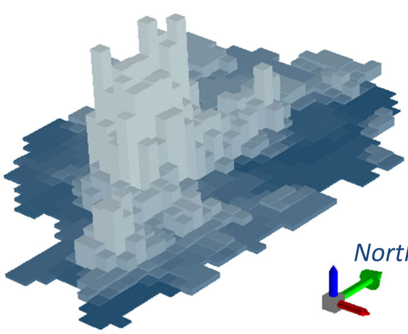
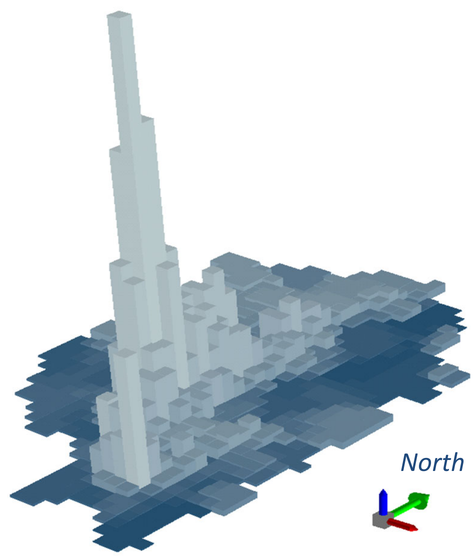


Figure 3 Employment Density



[5] The number of firms is always endogenous, as determined by monopolistic competition.

Baseline data, population and employment

The population and residential data shown in Figure 2 are based on the Population and Housing Census of 2010 (BBS 2011) at the union level. To best fit the model, we take households as the unit of observation and then re-scale the resulting spatial distribution of households by average household size to generate a spatial distribution of population. Following BBS (2011) we break the population down into those who report having completed secondary education or tertiary education, whom we define as skilled; the remainder of the working age population is defined as unskilled. We assume that the household head is the primary provider of labor, in which case 36 percent of households are classified as skilled. We also classify households into occupants of modern or traditional housing. This classification is based on building type, and the census reports four types of materials, namely, pucka, semi-pucka, kutcha and jhupri. We identify pucka housing as modern housing, which classifies 42 percent of the housing of the Greater Dhaka area as modern. Thus, we know, for each union, the number of households of each type (skilled/ unskilled) in housing of each type (modern/traditional).

Our data for the productive side of the economy are built up from employment data at the establishment location taken from the Economic Census 2013 (BBS 2014). The Economic Census reports 4-digit industry codes (BSIC 2009) and allows us to establish employment in manufacturing, non-tradable-services and tradable-services in each union. Tradable-services include financial services, professional and business services, information services, hospitals, universities, and air, railway and seawater transport related services. Additionally, the Population and Housing Census 2010 shows a significant proportion of households working in agriculture. We assume those who work in agriculture will work and live within the same union and are low-skilled, and we take the number of households classified as employed in agriculture from this data set.

Transport Network

The transport network is mapped in 2011 using data from the Revised Strategic Transport Plan (DTCA 2015) and OpenStreetMap (2015). Travel times are estimated for both pedestrians and motorists. Most of the low-skilled workers in Dhaka walk to work and are therefore classified as pedestrians. We assume that these pedestrians can travel at 5 km/h, travelling to the nearest point on the road network and then following the roads through the city. Skilled workers are assumed to have access to motorized transport. We assign travel speeds for vehicles along different types of roads according to the number of lanes, with vehicles able to travel at 15km/hour on one lane roads, 20km/hour on two lane roads, and 60km/hour for four lane or wider roads. Network analysis is then conducted to find the shortest route between each pair of unions, taking into account the location of roads and the travel times down different types of roads. When we project Dhaka to 2035, we assume road and Mass Rapid Transit (MRT) investments as planned in the Revised Strategic Transport Plan (DTCA 2015), allowing low-skilled workers to use the MRT or travel on foot, whichever is quicker, and high-skilled workers to also have the option of driving. Congestion on roads increases proportionally with the number of high-skilled workers in the city, reflecting the number who use motorized transport, and decreases with the number of kilometers of lanes of highway.

Parameters

Where possible, estimates of parameters for the model use data sources from Dhaka. Household consumption shares are estimated from the 2010 Bangladesh Household Income and Expenditure Survey (BBS 2010). Input-Output matrices are constructed for each sector for the Asian Development Bank's 2006 calculations (ADB 2016), aggregated into our sectors. Other parameters are derived using sources from the economics literature, with details provided in the appendix.

2.3 Calibration

Given technology, preferences, geography (the connectivity structure) and endowments (labor of each type and land in each place) the model computes the equilibrium, determining land use, location of residence and employment, and consumption and production. The model is calibrated by finding productivity and amenity values, for each productive sector and household type (by skill and housing type) in each place, such that the model exactly fits the base data for 2011. Maps documenting the employment in each union, the population in each union, as well as the distribution of rents, wages, and the amenity and productivity parameters, are provided in the appendix.

3. Projection to 2035: Scenario A

The model is calibrated to 2011, but the policy experiment – the dike and associated transport improvements – will not be completed until the early 2030s. The base-line for the experiment has therefore to be constructed, and this is done by using the Dhaka Structure Plan 2016-2035 (RAJUK 2016) in combination with our model, to project out to 2035. The Dhaka Structure Plan 2016-2035 (RAJUK 2016) provides the following as 'data'. Total population of the Greater Dhaka area reaches 24.6 million in 2035, so the average annual population growth rate between 2010 and 2035 is 2.3% percent. Of the population in 2035, 40% are high-skilled (up from 37% in the 2011 data). At a sectoral level, total factor productivity is assumed to grow at 1% per year in each sector. We impose the assumption that the value of land outside the city grows at the same rate as the increase in productivity.

We revise connectivity to include pre-planned transport investments, including 42.3 km of Bus Rapid Transit and 60.1 km of Mass Rapid Transit, both of which are used by low and high-skilled workers if it shortens their journey times. Approximately 1,200 km of lanes of road are also built, a combination of the widening of existing routes by adding new lanes, and the construction of entirely new highways. These are shown in maps in the appendix. The increase in high-skilled population, who have access to motorized transport, increases the number of cars on the road, whereas at the same time there is an increase in the number of kilometers of road lanes. We combine these two variables into a number of vehicles per kilometer of road, which is assumed to have a proportional impact on congestion, i.e. twice as many vehicles per road km would halve travel speeds in the city.

City growth will be met at both the intensive and extensive margin. The intensity at which land is used on the urban fringes is endogenous to the model, as land can be used alternatively for non-urban activities at a fixed rent. On average, 88% of available land in each union is developed in 2011, amounting to 43% of the greater urban area, with more distant unions typically less developed. This rises to 64% of the urban area in our baseline in 2035, Scenario A, as the increase in population and economic activity is accommodated at both margins. We also assume some development of land in East Dhaka as per the current trends, evident through the infilling of land with sand in order to construct property. This is assumed to only be feasible on the highest land within East Dhaka. Infill land is of poor quality and so is assumed to have the same productivity and amenity parameters as current 2011 infill land in East Dhaka.

The projection to 2035 is based largely on aggregate variables - changes in technology, total endowments and connectivity - and we use the calibrated model to predict the detailed spatial allocation of employment and residential activity across the 2035 city, and hence the implications for Dhaka's income and economic structure. Firms and households choose their location, production and consumption as stated in the model, given the productivity and amenity parameters revealed through the calibration process.

Table 1 reports some of the outcomes for Dhaka and East Dhaka that come from this projection. Reflecting the assumptions made from the structural plan, population rises by 74%, the equivalent of 2.3% annual population growth, spread across both East Dhaka and the rest of the city.

The high-skilled population increases by 93.2% to become 40% of the total, as shown in Figure 4. Figure 5 shows that 41% of the population are living in traditional housing, a lower share than in 2011; modern housing, which can be built tall, is increasingly demanded to host the growing population. Productivity growth across all sectors of the economy, together with the changing size and composition of the labor force translate into a near doubling of real income per capita, rising from a base level of 100 to 193.5. The increase is particularly large for the low-skilled, whose mean real income per capita rises to by 103.5%, compared to a rise of 76.8% for the high-skilled. The narrowing differential is due to the assumed greater increase in supply of skilled labor over this time period, both through migration and improved education rates.

Employment rises simultaneously to the population growth, with much employment growth on infill land in East Dhaka and on the fringes of the city where previously undeveloped land is available, as well as further densification in the city center. The total impact is an increase in the GVA of Dhaka of 239.5%, which equates to approximately 5.2% growth per year. Total land rents generated in the city increase by 241.8% of the 2011 level, a slightly larger increase than the total wage income (234.6%) as a result of the decreasing land-to-labor ratio. An implication of increasing land rent and a rising share of skilled workers is a major shift from traditional to modern housing, both in East Dhaka and throughout the rest of the city.

Table 1. Growth to 2035

		2011 - levels			2035 – percentage change relative to base		
		East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population		933	13,170	14,102	67.9%	74.6%	74.2%
	High Skill	333	4,896	5,228	74.3%	94.4%	93.2%
	Low Skill	600	8,274	8,874	64.4%	62.8%	63.0%
Employment		237	4,763	5,000	91.5%	72.9%	73.8%
	High Skill	68	1,732	1,800	98.1%	93.0%	93.1%
	Low Skill	169	3,031	3,200	88.8%	61.5%	62.9%
Wage income		2,188	46,719	48,907	262.8%	233.3%	234.6%
	High Skill	979	25,540	26,518	239.6%	235.6%	235.8%
	Low Skill	1,209	21,179	22,389	281.6%	230.5%	233.3%
Land Rent		573	9,827	10,400	213.1%	243.5%	241.8%
GVA		2,645	55,055	57,700	259.0%	238.6%	239.5%
Real Per Capita Income (Utility)				100			193.5
	High Skill			100			176.8
	Low Skill			100			203.5

Notes: Population and employment, thousands: income, GVA, Millions of 2015 USD.

The sectoral pattern of employment is reported in Figure 6. Much the largest increase in employment is in manufacturing, in line with the city's existing comparative advantage. Initially (in 2011) 32% of all jobs are in manufacturing, rising to 39% in 2035. This is consistent with expected growth patterns reported in the structural plan (RAJUK, 2016), which predicts further growth in the garment industry (currently 49% of formal jobs in Dhaka) and in leather goods. The growth in manufacturing jobs occurs particularly at the expense of jobs in tradable-services which fall from 9% to 5% of city employment, as the city specializes in manufacturing and becomes an increasing net importer of tradable-services. Non-tradable-services employment increases between the two years, but falls slightly in relative terms from 59% of city employment to 56%. The fall in the relative share of non-tradable-services jobs is partly attributable to the decline in the share of the urban population that is low-skilled. The growth in manufacturing employment occurs alongside a growth in land use by the manufacturing sector, a land intensive sector. Specifically, 34% of the total rents in the city were initially generated by manufacturing, rising to 37%.

Figure 4: Population by skill level, in thousands in 2011 and 2035

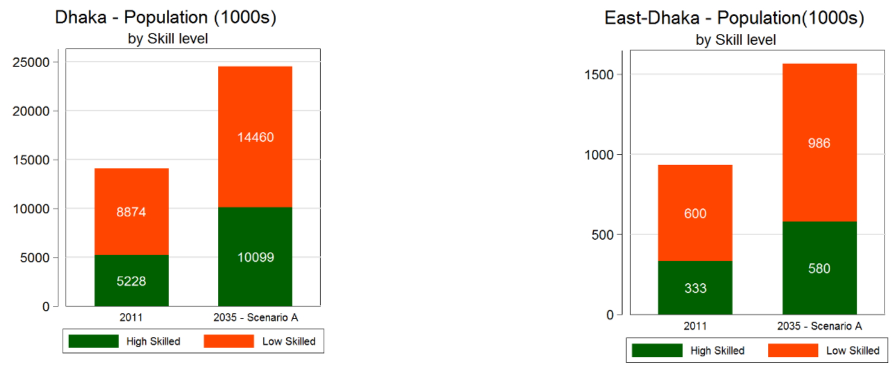


Figure 5. Population by housing type, in thousands in 2011 and 2035

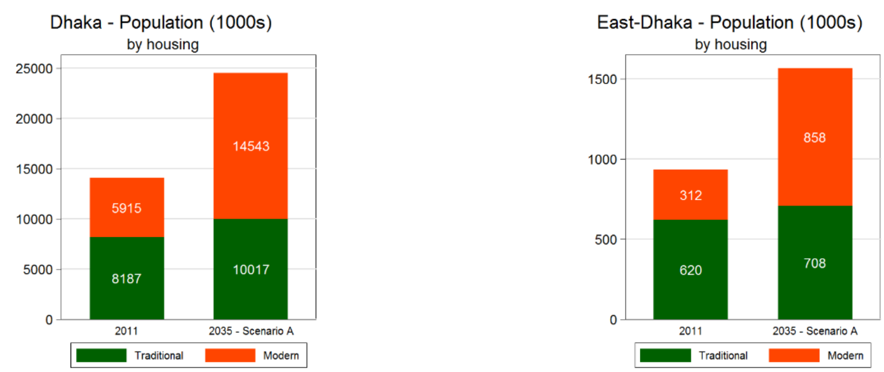
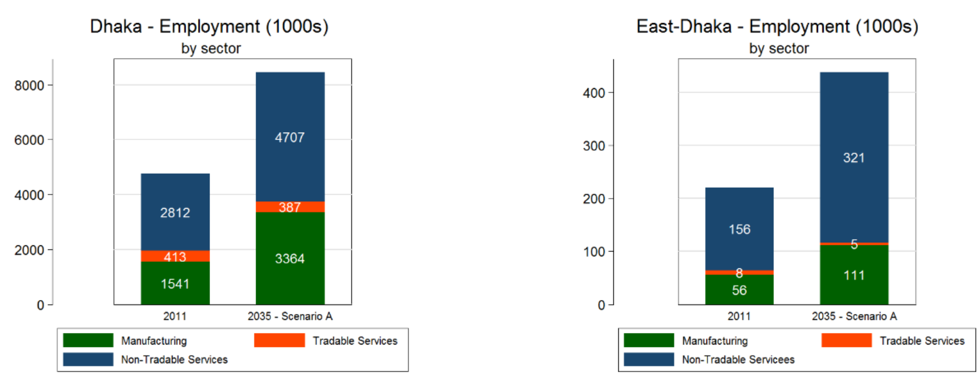


Figure 6. Employment by sector, in thousands in 2011 and 2035



4. Policy Experiments

In this section we present our main results on the impact of flood risk reduction and transport improvements on Dhaka. We look first, in section 4.1, at construction of the Eastern embankment and associated measures that reduce the risk of flooding in East Dhaka (scenario B). In section 4.2 we consider additionally the construction of further transport improvements (scenario C). Section 4.3 then looks at the impact of potential measures to reduce the costs of business for tradable-services in East Dhaka, designed to stimulate tradable-services in this part of the city, alongside increased provision of services for modern housing (Scenario D). We consider how this might change the composition of development and the overall welfare impacts on the city.

4.1: Scenario B: Reducing flood risk

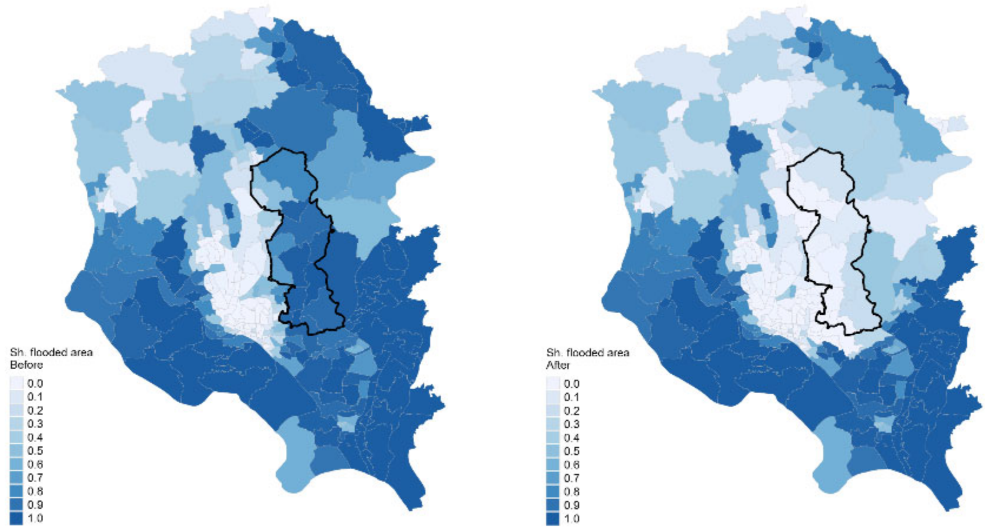
In this scenario an embankment and flood protection measures are built which reduce the risk of flooding throughout East Dhaka, as documented in Figure 7. The reduction in flood risk is modeled in two ways: 1. the share of land that is developable increases, increasing the total land area in East Dhaka by 36km^2 to a total of 102km^2, and in the city as a whole by 118km^2, of which most is to the south and east of the East Dhaka area; 2. the quality of the land in East Dhaka improves, which we model by raising the productivity and amenity parameters to the median of these parameters in the rest of Central Dhaka, a level representing the better organized and serviced areas of the city.[6]

Table 2 shows the aggregate economic effects of these measures. We report the effects as changes under three different steps of economic adjustment; first for a 'closed' city, i.e. with total population fixed at its scenario A level, and second for an open city, drawing migration from the rest of the country. These two cases assume no productivity spillovers. Finally, we allow for productivity spillovers (localization economies) in the tradable-services sector.

[6]The productivity and amenity parameters in Central Dhaka vary considerably, with a number of unions dense with traditional housing. As the embankment would free up vast areas of land all at once, we envisage in this first scenario some degree of better organisation in the development of this land, with initially large plots ready to be developed. We therefore use the median of the values in Central Dhaka. Note, this is probably an underestimate of the impact, as further areas of land beyond the fringes of East Dhaka also face a decreased flood risk as a result of the barrier. These changes are modeled solely through an increase in the quantity of land, without any additional increase in the quality.

Figure 7: Share of land that floods

Scenarios A **Scenarios B, C and D**



The changes in scenario B mean that firms and households have access to a greater supply of land which, all else equal, reduces the rent per unit area hence the costs faced by firms and by households for housing. In addition, productivity and amenity improvements in East Dhaka lead to localized boosts to the demand of land, as firms and households face a greater potential profit or utility benefit from location in East Dhaka.

The response is movement of households and firms into the affected areas. The residential population of East Dhaka nearly trebles and employment more than trebles (Table 2.B1). Since population and employment in the city as a whole are assumed unchanged, population and employment in the rest of Dhaka fall by 12%. GVA in the city as a whole increases by 3.0%, with wage income rising more than total land rents; while there has been a 12% increase in the total land area, average rents per unit land area have fallen, combining to create a 2% total rent increase. Real per capita income increases by 4.5%.

'Opening' the city (i.e. letting in-migration occur) results in growth of population and employment of 5.9% (Table 2.B2), or just under 1.5 million people. This gives somewhat larger increases in East Dhaka, and reduces the fall in population elsewhere in the city. The increase in GVA is now 9.7%, and per capita utility increases by 5%.

The final block of Table 2, (Table 2.B.3) assumes that localization economies are 1.5% in tradable-services. The combined effect is to increase Dhaka's GVA by 10.3%, or over 20 billion USD, and raise average per capita income across the city by 5.3%.

Table 2. Scenarios A and B

	Scenario A: Business as Usual			B1: Constant Total Population % Change from Base		
	East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population	1,566	22,993	24,559	179.1%	-12.2%	0.0%
Employment	454	8,237	8,691	219.8%	-12.1%	0.0%
Wage income	8,110	158,960	167,070	300.3%	-12.0%	3.2%
Land Rent	1,833	34,461	36,294	356.8%	-16.9%	2.0%
GVA	9,702	190,291	199,993	318.4%	-13.1%	3.0%
Real Per Capita Income (Utility)			100			104.5

	B2: Endogenous Population % Change from Base			B3: Endogenous population and localization economies: % Change from Base		
	East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population	196.6%	-7.1%	5.9%	197.7%	-6.8%	6.2%
Employment	236.4%	-6.8%	5.9%	236.7%	-6.5%	6.2%
Wage income	321.7%	-6.2%	9.7%	322.9%	-5.6%	10.4%
Land Rent	385.4%	-11.3%	8.8%	387.0%	-11.0%	9.1%
GVA	341.7%	-7.3%	9.7%	343.0%	-6.7%	10.3%
Real Per Capita Income (Utility)			105.0			105.3

Notes: Population and employment, thousands: income, GVA, Millions of 2015 USD.

These numbers are aggregates, and we now look at results by skill level, by sector, and in greater spatial detail. We compare scenario A with the full adjustment version of scenario B, (as in table 2.B3).

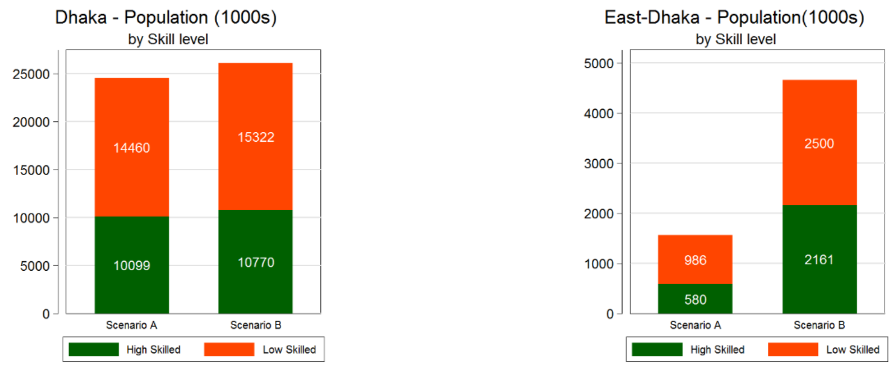
Figure 8 indicates flows of population into East Dhaka, away from central Dhaka and more outlying areas. The increase in population of East Dhaka is proportionately greater for the high-skilled (appendix table A1), and is drawn largely from areas close to the existing center of Dhaka. The low-skilled population growth in East Dhaka is concentrated within clusters along the western fringes where informal settlements are already developing today. The map shows that the low-skilled population also grows within areas to the north and south of East Dhaka, and falls in the historic urban center. The net effects are to increase the population density in East Dhaka from 14,560 people per km^2 to 40,070 people per km^2, closer to levels seen in Central Dhaka where the business as usual population density is 64,960 people per km^2. There is little change in the share living in 'traditional' housing.

Turning to employment, the number of jobs in East Dhaka grows threefold from 454,000 to 1,513,000. Figure 9 shows how this change in employment and output varies by sector. The increase in land supply in East Dhaka is attractive to the most land-intensive sector, manufacturing. 919,500 manufacturing jobs relocate into this area, reducing the presence of manufacturing in the rest of the city. This is turn reduces the demand for land elsewhere in the city, lowering rents and allowing other sectors to expand, an effect that is enhanced by the falls in population density in similar areas as seen above. In particular this reduction in land rents benefits tradable-services, in which 279,000 new jobs are generated, predominantly in the old historic center. This reflects the future envisaged in the Structural Plan (RAJUK, 2016), which indicates that the growing IT and telecommunications sectors will likely further develop in the historic, dense city center. Non-tradable local services also expand to serve the increased population, generating an extra 340,000 jobs located particularly in areas where population growth is high.

In total, this means that the employment levels in East Dhaka grow by 237%, with this growth focused heavily in high-skilled employment. The displacement of manufacturing jobs into East Dhaka drives a fall in the employment elsewhere in the city of 6.5%. As both the employment and population in East Dhaka increase, so do the total rents and wage income generated in this area of the city, with the former growing by 387.0% and the latter by 322.9%. East Dhaka now contributes 22% of the city rental income, compared to 5% in Scenario A, and 19% of total GVA, compared to 5% in Scenario A.

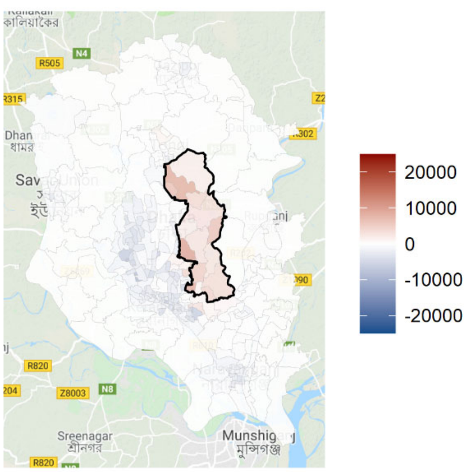
Figure 8   Population Effects of Scenarios A and B

a) Population, in thousands in Scenarios A and B



b) Changes in population density, people/km², by skill and by area.

High Skilled Population



Low Skilled Population

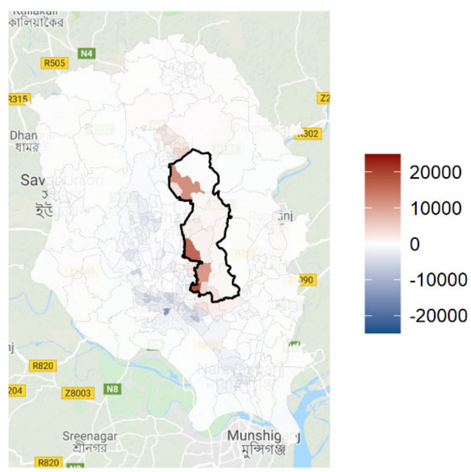
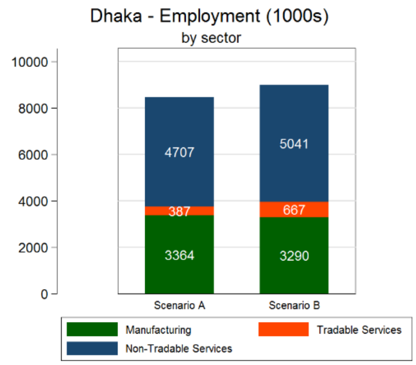
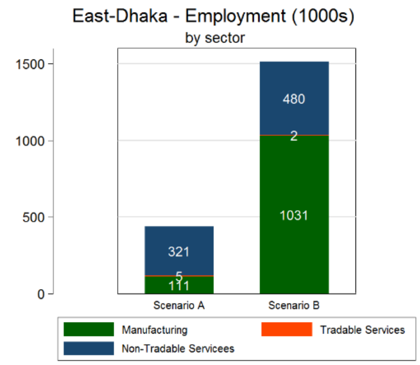


Figure 9. : Employment effects, Scenarios A and B

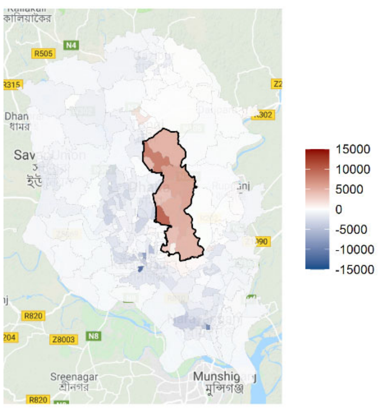
a) Employment by sector, in thousands, scenario A and scenario B



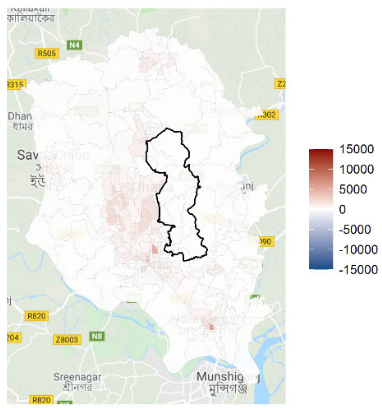


b) Changes in Employment Densities, people/km2

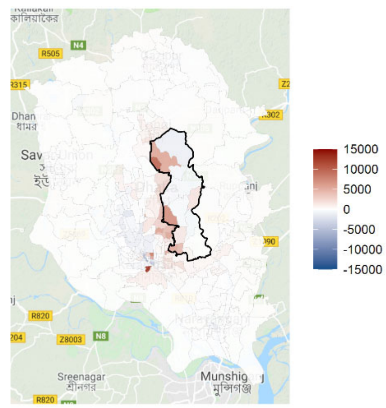
Manufacturing



Tradable-services



Non-tradable-services



4.2: Scenario C: Reducing flood risk and transport improvement

We now simulate scenario C, in which the embankment is modeled as before, however additional transport infrastructure is also built. This is shown in appendix Figure A11 with extra transport routes, including Mass Rapid Transit systems, in East Dhaka. The extra transport investments amount to 32 km more of BRT routes, 50km more or MRT routes, and nearly 1000km of extra road lanes compared to Scenarios A and B.

Table 3 gives the impacts of Scenario C (and for comparison also reports Scenario B), which changes relative to business as usual, Scenario A. Results are reported the case with endogenous population and localization economies (as in B3). The impacts on population, employment, rents, GVA and income per capita in the city as a whole, are nearly twice as large under this scenario than the previous. The additional transport investment enhances connectivity both to unions within East Dhaka, and across the rest of the city as travel times between many pairs of cells fall. This improved connectivity reduces shipping costs for all sectors and commuting costs for households.

Real incomes per capita, which rose by 5.3% in Scenario B relative to business as usual (Scenario A), are now 10.2% higher, with the high-skilled disproportionately benefitting. These gains are due to better access to goods and services, which reduces their effective price, lower commuting costs (particularly for the high-skilled who can potentially benefit from improved roads and the BRT, whereas the low-skilled only have access to the BRT), and higher wages. Total Gross Value Added rises 21.8%, compared to 10.3% without the transport improvements – generating an extra 22.9 billion USD above Scenario B. The greater increase in per capita income leads to higher rates of migration, and the total population growth is now 12.3%, or an extra 1.49 million people as compared to Scenario B. This increase is split among both high and low-skilled workers, with the former growing slightly faster.

Figure 10a shows that the increased population locate particularly in East Dhaka where again the growth in the high-skilled population is very large, as in Scenario B. The population elsewhere in the city still falls slightly despite the overall population growth, lowering pressures and congestion elsewhere. The population density in Central Dhaka falls further, to 57,100 people/km^2, compared to 59,300 people/km^2 in Scenario B, and 64,960 people/km^2 in A. In East Dhaka, it increases to 45,800 people/km^2.

Figure 10b shows the location of these changes in more detail. The overall trends are similar to Scenario B, with a few exceptions. First, the population increases throughout East Dhaka, including for the low-skilled; improved connectivity has enabled households to locate throughout most of this area. Second, for the low-skilled, population density rises in the areas to the east and south of East Dhaka. These areas were previously disconnected from most jobs within the city, but through the construction of extra lines of an MRT system these unions are accessible to those who do not have good access to private transport. This increases the potential of this space beyond East Dhaka to support the development of the city. The share of the population living in traditional housing lowers marginally to 44% in East Dhaka, and across the city as a whole.

Table 3. Scenarios B and C (changes relative to Scenario A)

		Scenario B Embankment			Scenario C Embankment and Transport		
		East Dhaka	**Rest of Dhaka**	**All of Dhaka**	**East Dhaka**	**Rest of Dhaka**	**All of Dhaka**
Population		197.7%	-6.8%	6.2%	214.5%	-1.4%	12.3%
	High Skill	272.6%	-9.6%	6.6%	303.0%	-4.6%	13.0%
	Low Skill	153.7%	-4.8%	6.0%	162.4%	0.8%	11.9%
Employment		236.7%	-6.5%	6.2%	265.5%	-1.6%	12.3%
	High Skill	511.4%	-13.6%	6.6%	515.7%	-7.1%	13.0%
	Low Skill	121.5%	-1.6%	5.9%	160.6%	2.1%	11.8%
Wage income		322.9%	-5.6%	10.4%	367.8%	4.5%	22.1%
	High Skill	583.9%	-11.2%	11.1%	619.0%	-0.1%	23.0%
	Low Skill	135.0%	1.3%	9.6%	186.8%	10.0%	21.0%
Land Rent		387.0%	-11.0%	9.1%	423.7%	-2.2%	19.3%
GVA		343.0%	-6.7%	10.3%	387.2%	3.2%	21.8%
Real Per Capita Income (Utility)				105.3			110.2
	High Skill			105.4			110.5
	Low Skill			104.9			109.6

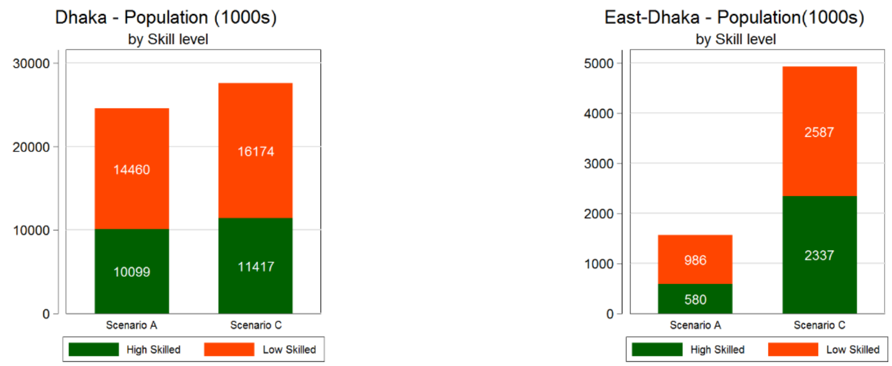
Notes: Population and employment, thousands: income, GVA, Millions of 2015 USD.

Figure 11 shows the sectoral impacts, in which manufacturing again drives the increase in employment in East Dhaka, however to a slightly lesser extent than in Scenario B. The better access to East Dhaka has made it more desirable for households to locate there, increasing the residential demand for land and reducing the number of manufacturing firms that relocate into this area.

As a result of the increased population in East Dhaka and beyond, non-tradable-services also increase in this area, serving the population near to their point of residence. Finally, because the increases in population and employment are that much higher, we no longer observe the same decreases in manufacturing and tradable-services employment in some areas of the city as we previously did; areas either remain with a relatively constant level of employment in these sectors, or see an increase in employment in these sectors. This is particularly evident in the garment industry hubs to the North West of the city, which are now better connected to more distant unions, allowing their workforce to live further from work, and freeing up land for an expansion of manufacturing and tradable-services in this area.

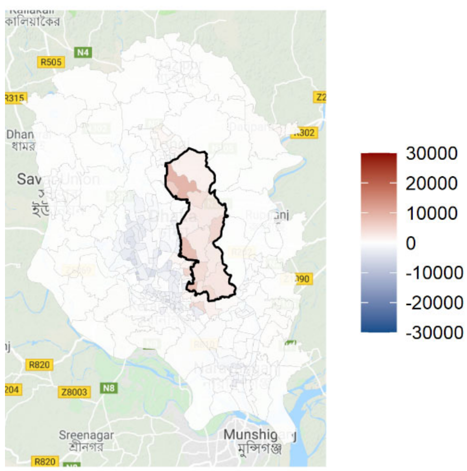
Figure 10. Population Effects of Scenarios A and C

a) Population, in thousands in Scenarios A and C



b) Changes in population density, people/km², by skill and by area.

High Skilled Population



Low Skilled Population

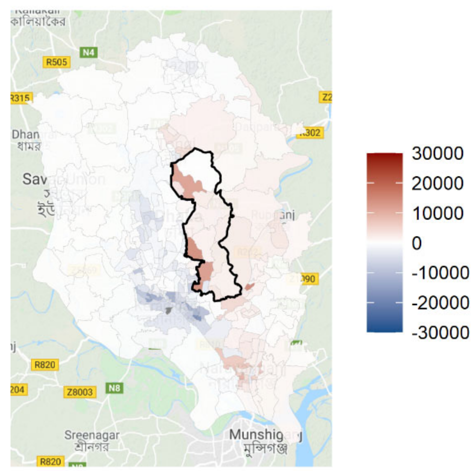
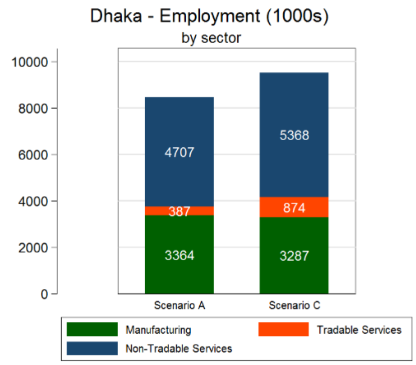
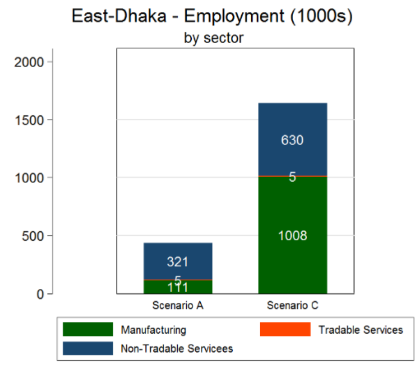


Figure 11. Employment effects, Scenarios A and C

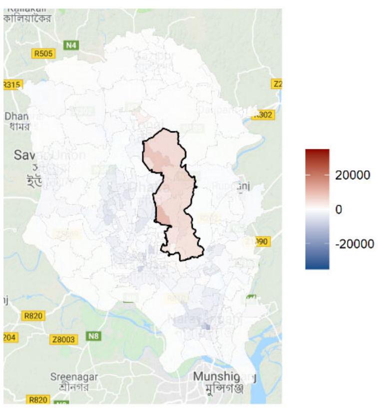
a) Employment by sector, in thousands, scenario A and scenario C



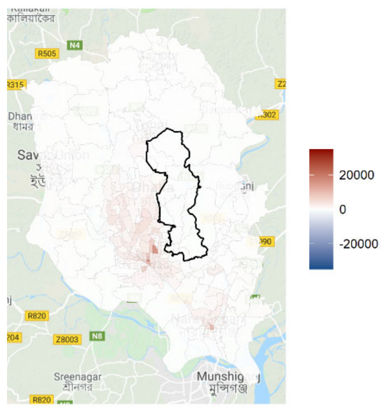


b) Changes in Employment Densities, people/km2

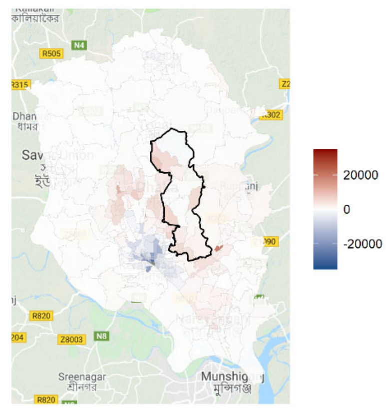
Manufacturing



Tradable-services



Non-tradable-services



4.3: Scenario D: Reducing flood risk, transport improvement, and reduction in the costs of doing business

In the final scenario D, we consider all the above investments, plus additional measures targeting modern housing and the tradable-services sector. The basis for the former is government investment in sites, services, schools and other amenities to encourage modern housing developments in East Dhaka. In terms of the model, we raise the amenity parameter for modern housing in East Dhaka to the 80th percentile of the value seen in Central Dhaka, the better quality areas of the existing city.

The latter measures are intended to encourage the formation of a new cluster of tradable service firms in East Dhaka. Policy is focused on a single union, and we model two components. The first is to match the productivity parameter of the current 'best' area for tradable-services in central Dhaka, assuming that in a new, as yet undeveloped, part of the city, the government can create one union which is as attractive for tradable-services firms as the most attractive area in central Dhaka. The second is a package of direct cost-reducing measures for tradable service firms in this union, such as measures to reduce the regulatory burden on firms, the provision of targeted infrastructure, or a direct reduction in taxes to firms in these areas. We do not attempt to model these specifics in detail, simply treating them as a cost reduction for targeted firms.

Table 4 shows the impact of these measures compared to the Business as Usual, Scenario A (and, in Table 4, Scenario C also reported to allow comparison). The new Scenario D has the East Dhaka amenity boost and single union tradable-service sector productivity boost, as described in preceding paragraphs. We set the cost reduction for this sector / union at 20%; later, we show the range of impacts for various levels of cost reductions.

This Scenario D package of measures stimulates tradable-services production, ensuring this sector expands and generates extra GVA. The total impact on the city is a boost in output of 39.3% relative to Scenario A, or 78.6 billion USD, 35 billion more than in the previous Scenario C. This extra output boosts real incomes, and at the new equilibrium the real income per capita of high skilled households has risen 18.1%, and of low-skilled by 16.3%. This new equilibrium takes into account that higher real incomes lead to increased migration into the city, boosting total production further. The population increases 20.4% relative to the Business as Usual Scenario A, an additional 1.99 million people compared to the Scenario C with the embankment and transport investments alone. The growth is particularly evident in the high-skilled population, who experience a greater increase in their per capita real-income.

Table 4. Scenarios C and D (changes relative to Scenario A)

		Scenario C Embankment and Transport			Scenario D Embankment, Transport and targeted amenity, productivity & cost reduction (20%)		
		East Dhaka	**Rest of Dhaka**	**All of Dhaka**	**East Dhaka**	**Rest of Dhaka**	**All of Dhaka**
Population		214.5%	-1.4%	12.3%	284.8%	2.4%	20.4%
	High Skill	303.0%	-4.6%	13.0%	458.8%	-4.7%	21.9%
	Low Skill	162.4%	0.8%	11.9%	182.4%	7.5%	19.4%
Employment		265.5%	-1.6%	12.3%	405.3%	-0.8%	20.4%
	High Skill	515.7%	-7.1%	13.0%	987.1%	-16.9%	21.9%
	Low Skill	160.6%	2.1%	11.8%	161.3%	10.1%	19.4%
Wage income		367.8%	4.5%	22.1%	659.3%	7.4%	39.1%
	High Skill	619.0%	-0.1%	23.0%	1289.9%	-7.8%	40.7%
	Low Skill	186.8%	10.0%	21.0%	205.0%	26.1%	37.2%
Land Rent		423.7%	-2.2%	19.3%	616.1%	6.9%	37.6%
GVA		387.2%	3.2%	21.8%	668.7%	7.2%	39.3%
Real Per Capita Income (Utility)				110.2			117.6
	High Skill			110.5			118.1
	Low Skill			109.6			116.3

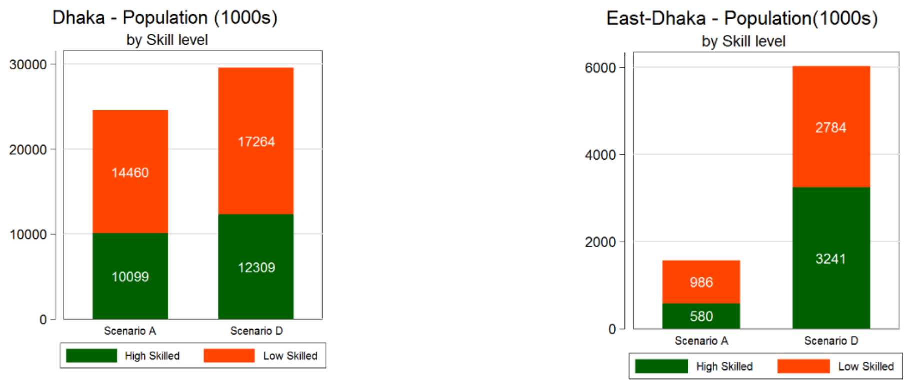
Notes: Population and employment, thousands: income, GVA, Millions of 2015 USD.

Figure 12 shows the impact of this on the composition of the population and on its location. The population increase, as in the previous scenarios, is disproportionately located in East Dhaka. Boosting the amenity levels for modern housing in East Dhaka to the 80th percentile of those observed in central Dhaka raises the share of modern housing to 73%, from 55%. This is not at the expense of density, as modern housing can be built as multi-storey apartment blocks, and we observe an increase in the population density in East Dhaka to 56,000 people per km^2, further reducing the pressures on the old city. As in the previous scenario, the low skilled population density also grows in areas to the east and south of East Dhaka, as a result of improved transport connections into this area.

Figure 13 shows the impacts on employment. Tradable-services employment increases in response to the cost reduction measures, relocating into East Dhaka and away from the historic center; with the 20% cost reduction for tradable-services, this sector comes make up 43% of East Dhaka's employment, and 9.6% of the city's as a whole, compared to just 4.6% in Scenario A. There are over 982,000 jobs in tradable-services in East Dhaka, essentially all of the tradable-services jobs in the city focused in one cluster. The increase in tradable-services begins to crowd out manufacturing both within East Dhaka and citywide. Non-tradable-services now move into the historic center, where retail and other local services fill the space vacated by the relocation of these other industries.

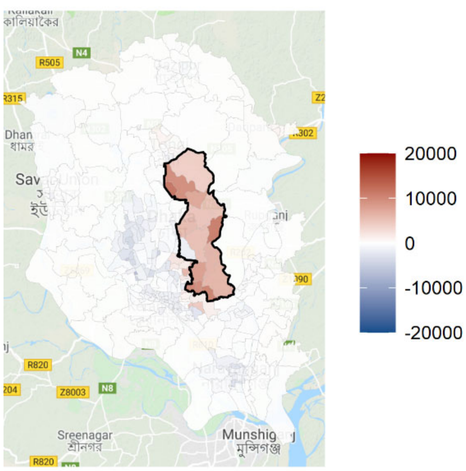
Figure 12. Population Effects of Scenarios A and D

a) Population, in thousands in Scenarios A and D



b) Changes in population density, people/km², by skill and by area.

High Skilled Population



Low Skilled Population

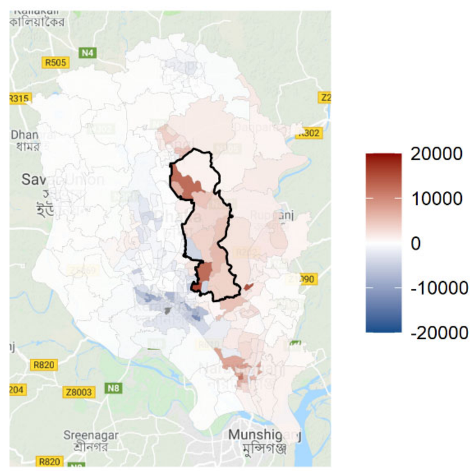
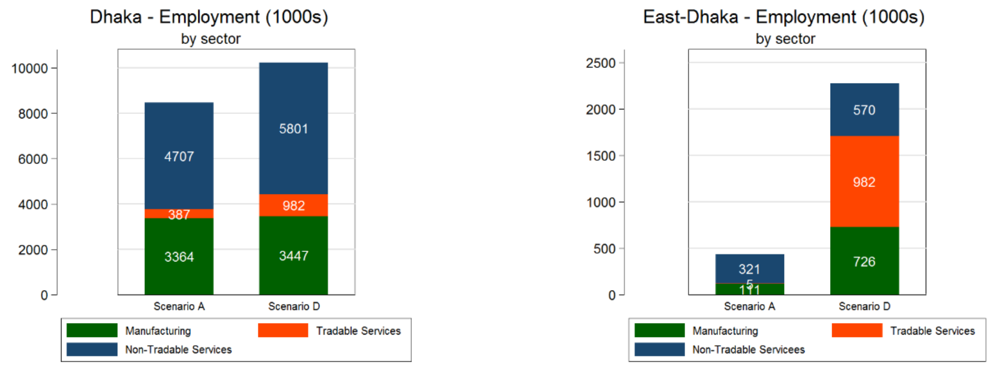


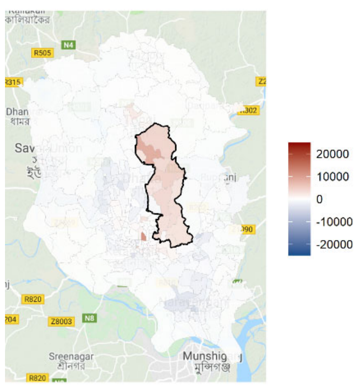
Figure 13. Employment effects, Scenarios A and D

a) Employment by sector, in thousands, scenario A and scenario D

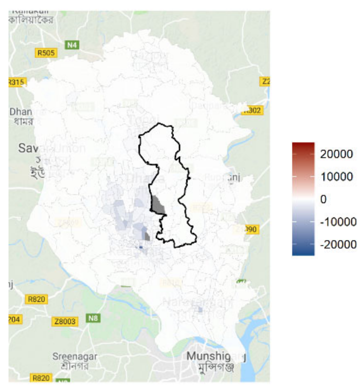


b) Changes in Employment Densities, people/km2

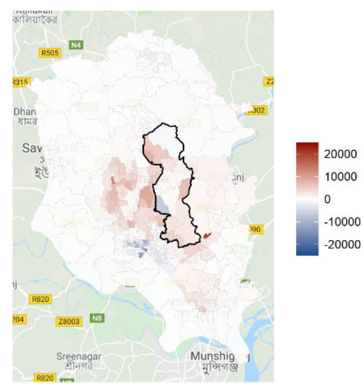
Manufacturing



Tradable-services



Non-tradable-services



These simulations indicate that a large enough cost reduction can relocate tradable-service activity and lead to the creation of a sector cluster in the targeted area of East Dhaka. How sensitive is this response to the size of the subsidy? To investigate this we simulate this scenario under various levels of cost reduction measures (maintaining the assumption that policy is targeted to one specific union with productivity equal to the 'best' area for tradable-services in central Dhaka). Figure 14 shows that as the reductions in business costs become greater, tradable-services expand in East Dhaka. When the productivity of the union is set to that of the best area in central Dhaka, with no additional cost reduction measures, there are 135,000 jobs in tradable-services in the East, only a small share of the 874,000 tradable-services jobs in the whole city (column D 0% of Figure 14). This share expands as the costs are further reduced, and finally by 20% cost reductions, all of the tradable-services firms have relocated into East Dhaka, with a total of an extra 110,000 jobs in tradable-services relative to Scenario C in the city as a whole, as shown in Figure 15.

Figure 14. Employment in East Dhaka

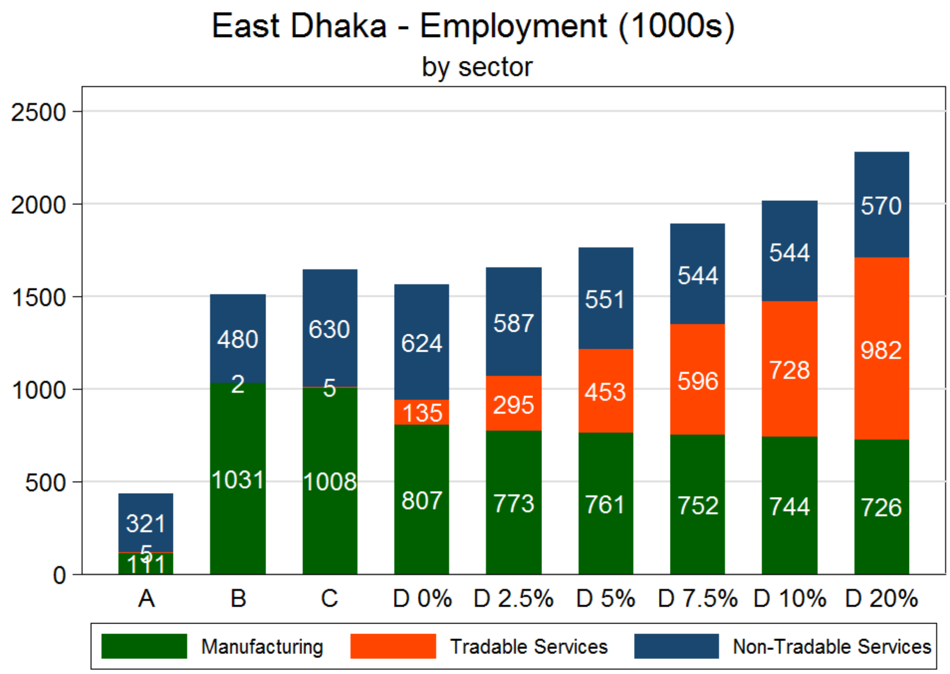
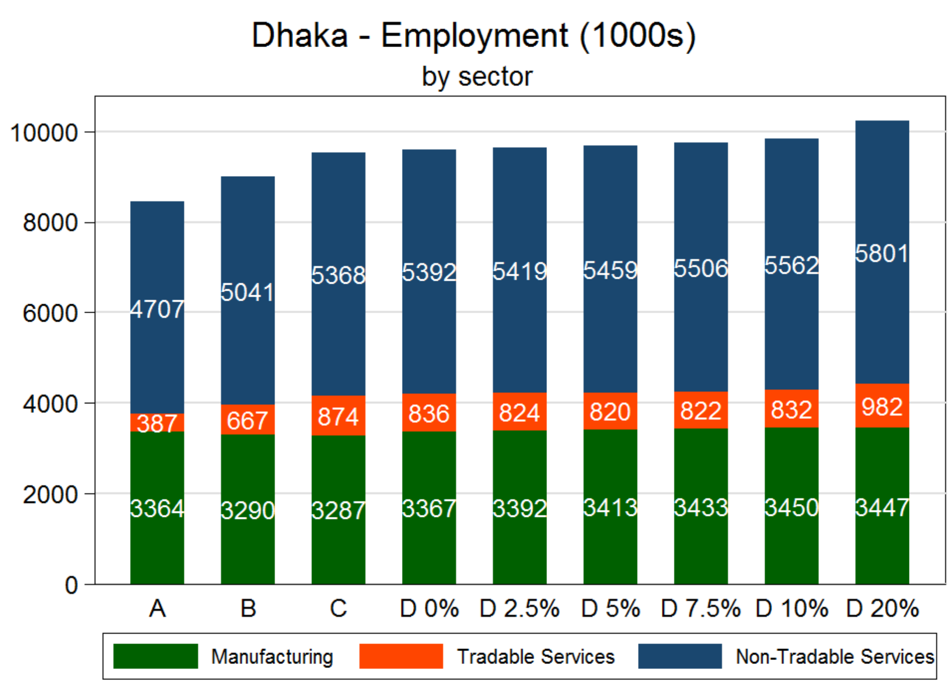
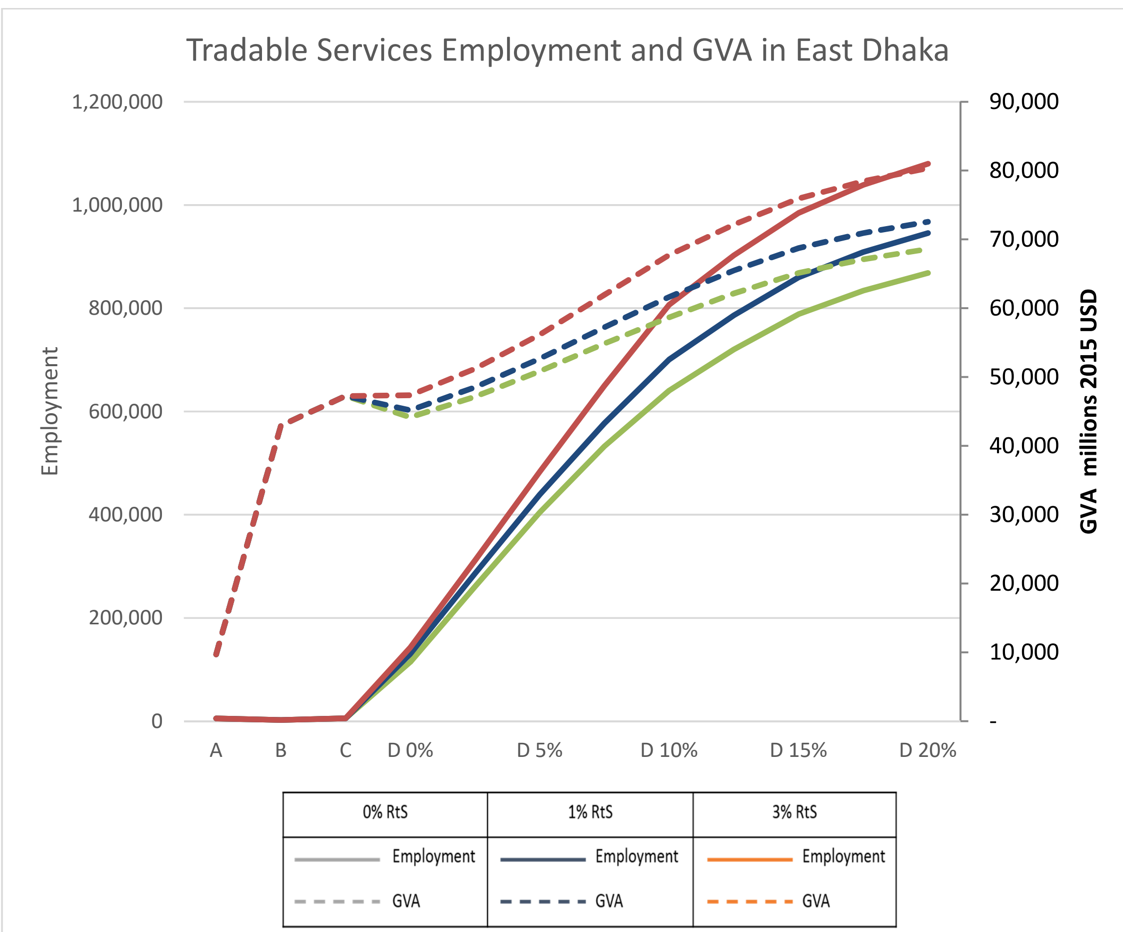


Figure 15. Employment in Dhaka



The size of the new cluster that forms in East Dhaka, as well as the ease with which the government can entice firms to relocate into this area, depend on a number of further factors, one of which is the size of the agglomeration economies in the tradable-services sector. The stronger the agglomeration effects, the greater is the benefit to forming a new (and larger) center, although it may also provide some inertia, as firms are initially unwilling to move out of the existing hub in central Dhaka. Figure 16 shows the size of the tradable-services sector in East Dhaka at different levels of cost reduction and under three different values of returns to scale: no returns to scale, 1% returns to scale and 3% returns to scale. By the time the extra 20% cost reduction measures are applied, all tradable-services firms move into East Dhaka, and the total tradable-services employment is even larger than under the setting with no returns to scale. At these levels of returns to scale there is little evidence of inertia – expansion of the East Dhaka hub is continuous in the subsidy, but the magnitude of returns to scale has a large impact on the income and employment generated by the sector. Total GVA in East Dhaka is some 15% higher (and employment 13% higher) with returns to scale at 3% rather than at 0%.

Figure 16: Impacts of Scenario D under different Returns to Scale



5. Conclusions

The development of East Dhaka is a potentially transformative project for the city of Dhaka, and the country of Bangladesh. The World Bank report by Bird et al. (2018), addresses the potential risks and benefits of developing this area, versus doing nothing and leaving the area on the same development path as it is today. The risks the city faces, from flooding, congestion, and an urban messiness from a lack of investment in good quality services, are affecting the city today and will increasingly do so in the future, unless some action is taken. East Dhaka provides a unique opportunity to address some of these challenges. The modelling described in this paper suggests that the construction of the Eastern Embankment and related flood protection measures, increasing the availability of land near the heart of the city, might be expected to lead to large returns.

In order to examine in more detail the potential size and the distribution of these returns, the model and simulations in this paper have been developed as a background paper to the World Bank report. The use of the general equilibrium framework allows for consideration of the interaction between different players in the city. Firms and households all interact across the urban space, and so policies that directly may affect only one group will have subsequent indirect impacts on others within the city. The modeling builds on recent developments in the economic literature, differentiating households by skill, commuting modes and housing preferences, firms by sector, and sectors by their production technologies and the tradability of their output. This creates a model which replicates the essential elements of the geography of the current city today. The framework also allows us to elaborate on potential investment scenarios the city may choose to undertake, with a benchmark situation in which the city develops without significant extra investments, against which other scenarios can be quantifiably compared. The size of economic returns, and whether these are in the form of wage incomes for high or low skill households or rents for land-owners, are shown to vary significantly according to how the development of East Dhaka is planned and executed.

The scenarios simulated in this background paper are embedded in a wider framework of the institutional, geographical and environmental situation that Dhaka finds itself in today; these are addressed more thoroughly in the full report. The economic analysis of this background paper highlights the processes through which the impacts of these potential scenarios will be felt, and the relative size of these impacts. A successfully planned development of East Dhaka, with a geographically focused area in which business costs are further reduced to encourage new tradable-services firms, could lead to a large and transformative change for the city. By running through a range of scenarios, we document that the increases in GDP per capita for those living in the city can be from 5%, to as much as 17.6%. Combined with population growth enabled by the policy, the increase in GVA can be as much as 39%. Yet to achieve this requires coordinated policy: engineering, to construct the embankment, transport planning, to ensure the newly developable land is accessible, land policy, to encourage the allocation of land to high-value sectors, and service provision, to facilitate the construction of modern housing. Finally, there may also need to be soft policies that encourage the formation of clusters of firms in the newly developable areas that can boost the potential returns from the project, allowing the city to reap the benefits of potential agglomeration economies.

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Appendix

1. Model

Geography: The city contains $I + 1$ geographical cells, labeled by subscripts i, j. Of these, $I = 266$ are in the city and one (denoted 0) is the rest of the world. The area of cell i is $\overline{G_i}$. Cells differ in their connection to the transport network, their productivity and their amenity value. Households and firms are distributed endogenously across these cells, and a matrix of distances (and hence travel times) links cells. This matrix underpins different sorts of distance costs – for commuting, for moving goods and services, and for the spatial decay of productivity spillovers.

Production: There are 3 productive sectors, labeled by superscripts s = 1, 2 ...3. These are all monopolistically competitive, producing differentiated products as modeled by Dixit-Stiglitz.[7] Thus, the number of active firms in sector s at cell i is n_i^s. Each charges producer price p_i^s and ships output from cell i to cells j, incurring iceberg trade cost factor T_{ij}^s which varies according to sector. Products from the rest of the world arrive at price p_0^s and have n_0^s varieties (both exogenous). The elasticity of substitution between varieties in sector s is σ^s, so the CES price index for sector s products delivered to cell j is

$$P_j^s = \left[\sum_i n_i^s \left(p_i^s T_{ij}^s \right)^{1-\sigma^s} + n_0^s \left(p_0^s \right)^{1-\sigma^s} \right]^{1/(1-\sigma^s)}. \tag{A1}$$

Demand for a single sector s variety produced in i and sold across all cells j is x_i^s, given by

$$x_i^s = \sum_j \left(p_i^s \right)^{-\sigma^s} \left(T_{ij}^s \right)^{1-\sigma^s} E_j^s \left(P_j^s \right)^{\sigma^s - 1} \tag{A2}$$

where E_j^s is cell j expenditure on sector s.

Each cell i sector s firm maximizes profits, $\Omega_i^s = p_i^s x_i^s - c_i^s \left[x_i^s + f^s \right]$, where the second term is cost of production, with constant marginal cost c_i^s and fixed cost $c_i^s f^s$. The profit maximizing price is a constant mark-up over marginal cost,

$$p_i^s = c_i^s \sigma^s / (\sigma^s - 1). \tag{A3}$$

Firms make zero profits if they sell a fixed level of output $\overline{x}^s = (\sigma^s - 1) f^s$. Free entry and exit of firms gives condition:

[7] This section draws on the standard properties of the multi-location Dixit-Stiglitz model of competition. Details and derivations are in Fujita et al. (1999).

If $n_i^s > 0,\ x_i^s = \bar{x}^s$, else $n_i^s = 0,\ x_i^s < \bar{x}^s$. (A4)

Costs c_i^s are a CES function of prices of land, labor, and intermediates with elasticity of substitution η^s. The price of land available to sector s is r_i^s. There are two different sorts of labor, indexed by superscript ℓ =1 (high-skill) and ℓ =2 (low-skill) with wage rates w_i^ℓ. Intermediates are composite goods with price indices P_i^s, so the sector s cost function in cell i is

$$c_i^s = \frac{1}{a_i^s} \cdot \left[a^{ms}\left(r_i^s\right)^{1-\eta^s} + \sum_\ell a^{\ell s}\left(w_i^\ell\right)^{1-\eta^s} + \sum_z a^{zs}\left(P_i^z\right)^{1-\eta^s} + a^{fs}\left(p_i^f\right)^{1-\eta^s} \right]^{1/(1-\eta^s)}. \quad \text{(A5)}$$

Parameters $a^{ms}, a^{\ell s}, a^{zs}, a^{fs}$ measure the intensity with which respective inputs are used, and final term in this expression is the price of food, p_i^f, which enters the model only as input to the non-tradable-services sector (in particular retail and wholesale trade).

The productivity of each sector in each place is given by a_i^s. This consists of two components. One is a shift factor A_i^s, and the other is sector-specific agglomeration economies which depend, according to function $\mathrm{f}^s(.)$, on the number of firms in the sector weighted by some measure of proximity, θ_{ij}^s, so

$$a_i^s = A_i^s . \mathrm{f}^s\left(\sum_j \theta_{ij}^s n_j^s\right). \quad \text{(A6)}$$

It follows from this structure that each sector's supply and demands are as follows:

Value of output supplied by cell i: $p_i^s n_i^s x_i^s$.

Value of labor type ℓ demanded in cell i:

$$w_i^\ell L_i^{\ell s} = n_i^s\left[x_i^s + F^s\right]w_i^\ell \frac{\partial c_i^s}{\partial w_i^\ell} = n_i^s c_i^s\left[x_i^s + f^s\right]a^{\ell s}\left(w_i^\ell / c_i^s a_i^s\right)^{1-\eta^s}.$$

Value of intermediate z demanded by sector s in cell i:

$$P_i^z I_i^{zs} = n_i^s\left[x_i^s + f^s\right]P_i^z \frac{\partial c_i^s}{\partial P_i^z} = n_i^s c_i^s\left[x_i^s + f^s\right]a^{zs}\left(P_i^z / c_i^s a_i^s\right)^{1-\eta^s},$$

and similarly for food inputs to the non-traded services sector.

Value of land demanded by sector s in cell i

$$r_i^s G_i^s = n_i^s\left[x_i^s + f^s\right]r_i^s \frac{\partial c_i^s}{\partial r_i^s} = n_i^s c_i^s\left[x_i^s + f^s\right]a^{ms}\left(r_i^s / c_i^s a_i^s\right)^{1-\eta^s}.$$

Residential construction: There are two distinct types of housing, formal (h = 1) and informal (h = 2). The quantity of floor-space supplied per unit of land is chosen endogenously and denoted g_i^h. Additional floor space is delivered in different ways by the formal and informal sector. The formal sector chooses building height, at fixed cover (building footprint per unit land) and hence fixed quality, but with increasing marginal construction cost. At the other extreme, the informal sector is unable to build tall and has constant returns to building more single-storey buildings in a given area; but this increases crowding and lowers quality, reducing the utility of residents (and hence their willingness-to-pay) in more crowded areas.

For the formal sector, h = 1, rent per unit land takes the form $r_i^h = q_i^h g_i^h - c_i^h.\left(g_i^h\right)^\gamma$ where the price of floor-space is q_i^h, and the second term is construction costs, with level c_i^h and parameter $\gamma > 1$ denoting the elasticity of costs with respect to density (height). A developer's optimization problem is to choose g_i^h to maximize this. The rent maximizing value of g_i^h, and consequent optimized bid rent are:

For $h = 1$: $$g_i^h = \left[q_i^h / c_i^h \gamma\right]^{1/(\gamma-1)}, \qquad r_i^h = c_i^h(\gamma-1)\left[q_i^h / c_i^h \gamma\right]^{\gamma/(\gamma-1)}, \tag{A7}$$
with gross revenue $q_i^h g_i^h = r_i^h \gamma/(\gamma-1)$, and construction costs $c_i^h.\left(g_i^h\right)^{\gamma^h} = r_i^h/(\gamma-1)$.

In the informal sector, h = 2, rent per unit land takes the form $r_i^h = g_i^h\left\{q_i^h.\left(g_i^h\right)^{(1-\lambda)/\lambda}\right\} - c_i^h.g_i^h$. The first term is revenue, equal to the amount of floor-space supplied, g_i^h, times (in curly brackets) the price. This consists of two elements, q_i^h, the price of type h floor-space at unit quality, multiplied by a quality deflator, decreasing in floor-space per unit land, $\lambda \geq 1$. The second term is construction cost, now taken to be proportional to floor space. Floor space is chosen to maximize rent, taking q_i^h as constant but internalizing the possible negative impact of crowding on price. The rent maximizing value of g_i^h and optimized bid rent are:

For $h = 2$: $$g_i^h = \left[q_i^h / c_i^h \lambda\right]^{\lambda/(\lambda-1)}, \qquad r_i^h = c_i^h(\lambda-1)\left[q_i^h / c_i^h \lambda\right]^{\lambda/(\lambda-1)}, \tag{A8}$$
giving revenue $q_i^h g_i^h = r_i^h \lambda/(\lambda-1)$, and construction costs $c_i^h.\left(g_i^h\right) = r_i^h/(\lambda-1)$.

The iso-elastic functional forms mean that the shares of construction costs in revenue are $1/\gamma$, $1/\lambda$, and the shares of rent are $1-1/\gamma$, $1-1/\lambda$. We set parameters such that $\lambda > \gamma$, so the cost share is smaller in the informal sector than in the formal. The inequality also means that there are sharper diminishing returns to increases in floor-space in the informal sector (where crowding reduces price) than in the formal sector (where building taller raises unit construction costs).

The area of cell i that is used by housing of type h is denoted G_i^h so the quantity of floor-space of type h supplied in cell i is $G_i^h g_i^h$. It follows that the values of residential rent and of housing supply of housing in cell i are:

Value of residential rent in cell i: $\sum_h G_i^h r_i^h$

Value of type h housing supplied in cell i: h =1: $G_i^h r_i^h \gamma/(\gamma-1)$: h =2: $G_i^h r_i^h \lambda/(\lambda-1)$.

Construction occupies land and also uses labor and intermediate inputs.[8] The unit cost of building is Cobb-Douglas, so c_i^h is

$$c_i^h = K_i^h \prod_\ell \left(w_i^\ell\right)^{\mu^{\ell h}} . \prod_s \left(P_i^s\right)^{\mu^{sh}} \tag{A9}$$

where exponents sum to unity and parameter K_i^h is a cost parameter. Derived demands for inputs and labor used in housing construction are therefore:

Value of construction demand in cell i for labor of type ℓ:

$$\mu^{\ell 1} G_i^1 r_i^1/(\gamma-1) + \mu^{\ell 2} G_i^2 r_i^2/(\lambda-1)$$

Value of construction demand in cell i for inputs from sector s

$$\mu^{s1} G_i^1 r_i^1/(\gamma-1) + \mu^{s2} G_i^2 r_i^2/(\lambda-1).$$

Households: There are two different skill levels of households (=workers) indexed by ℓ, and the city population of households of type ℓ is L^ℓ. These households choose consumption bundles, and also make discrete choices of where to live (cell i), work (cell j), and what sort of housing to occupy (type h). Household utility is given by

$$u_{ij}^{\ell h} = \left(w_j^\ell + m_{ij}^\ell\right) b_i^{\ell h} t_{ij}^\ell \Big/ \left[\left(q_i^h\right)^{\beta^{\ell h}} . \prod_s \left(P_i^s\right)^{\beta^{s\ell h}}\right]. \tag{A10}$$

The first element in the numerator is income, with wage income depending on labor type and place of work, w_j^ℓ, and other income transfers denoted m_{ij}^ℓ. The second term, $b_i^{\ell h}$, is the amenity value to an individual of type ℓ of living in housing of type h in location i. This is a constant parameter (to be derived from calibration).[9] The third term, $t_{ij}^\ell \leq 1$, represents commuting costs. These impact utility directly and depend on distances traveled; they may

[8] Construction of structures by firms is subsumed in firms' overall cost functions.

[9] Eqn. (A10) can be written $u_{ij}^{\ell h} = \left(w_j^\ell + m_{ij}^\ell\right) B_i^{\ell h} \left(g_i^h\right)^{\beta^{\ell h}(1-\lambda)/\lambda} t_{ij}^\ell \Big/ \left[\left\{q_i^h . \left(g_i^h\right)^{(1-\lambda)/\lambda}\right\}^{\beta^{\ell h}} . \prod_s \left(P_i^s\right)^{\beta^{s\ell h}}\right]$

where the utility loss from crowding is explicit in the numerator and the market price of space (quality unadjusted) is the curly bracket in the denominator.

vary by worker type (some walk, others drive). The denominator is the price index. This is Cobb-Douglas across goods and housing, where the price of a unit of housing space of unit quality and of type *h* in cell *i* is q_i^h. Exponents sum to unity, and we add generality by allowing these shares to depend on both housing type and household type.[10]

Individuals choose where to live, where to work, and how to be housed. These discrete choices are captured by a choice function with parameter ζ giving the probability that an individual of type ℓ will live in *i*, work in *j* and occupy house type *h*, $\pi_{ij}^{\ell h}$.

For each ℓ: $\pi_{ij}^{\ell h} = (u_{ij}^{\ell h})^{\zeta} / \left\{ \sum_h \sum_i \sum_j (u_{ij}^{\ell h})^{\zeta} \right\}, \quad \sum_h \sum_i \sum_j \pi_{ij}^{\ell h} = 1.$ (A11)

If total city population of workers of type ℓ is L^{ℓ}, the number living in houses of type *h* in cell *i* is $L_i^{\ell h} = L^{\ell} \sum_j \pi_{ij}^{\ell h}$, and the total number working in cell *j* is, summing over the two types of housing, $L_j^{\ell} = L^{\ell} \sum_i \left(\pi_{ij}^{\ell 1} + \pi_{ij}^{\ell 2} \right)$.

Given the total number of households of each type, the wages and prices they face, and their location choices, consumer demand for goods and housing and their supply of labor are:

For each ℓ:

Value of household demand for sector *s* in cell *i*: $L^{\ell} \sum_j \left(\pi_{ij}^{\ell 1} \beta^{s\ell 1} + \pi_{ij}^{\ell 2} \beta^{s\ell 2} \right) (w_j^{\ell} + m_{ij}^{\ell})$

Value of demand for housing type *h* in cell *i*: $L^{\ell} \sum_j \pi_{ij}^{\ell h} \beta^{\ell h} (w_j^{\ell} + m_{ij}^{\ell})$

Value of supply of labor of type ℓ in cell *j*: $w_j^{\ell} L_j^{\ell} = w_j^{\ell} L^{\ell} \sum_i \left(\pi_{ij}^{\ell 1} + \pi_{ij}^{\ell 2} \right)$.

Rent, profits, and government: Household income contains a term m_{ij}^{ℓ} of 'other income'. This is, in aggregate, the total of rents and profits earned by the economy. For this baseline version of the model we assume that this income is distributed to households in a lump sum manner. The simplest form is equal division,

$$m_{ij}^{\ell} = m = \sum_i \left[\sum_s n_i^s \Omega_i^s + \sum_s r_i^s G_i^s + \sum_h r_i^h G_i^h \right] / \sum_{\ell} L^{\ell}. \quad \text{(A12)}$$

The first term in square brackets is total profits (equal to zero in the full equilibrium), and the other terms are commercial and residential land rents. In future versions of this model

[10] Expression (A10) is a maximum value function that incorporates optimal choice of continuous variables, i.e. consumption of goods and of floor-space. The quantity of floor-space, say y_i^h, enters the primal utility function in quality adjusted form $\left\{ \left(g_i^h \right)^{(1-\lambda^h)/\lambda^h} y_i^h \right\}^{\beta^{\ell h}}$.

government will be added, spending money on goods and services and raising revenue from a variety of tax instruments.

Equilibrium and market clearing: Demands for goods, housing, land and labor come from households, firms, the construction sector and (for goods) also 'exports' from the city. Thus, the value of spending on sector *s* products at location *i* is E_i^s ,

$$E_i^s = \sum_\ell L^\ell \sum_j \left(\pi_{ij}^{\ell 1}\beta^{s\ell 1} + \pi_{ij}^{\ell 2}\beta^{s\ell 2}\right)(w_j^\ell + m_{ij}^\ell) + \sum_z P_i^s I_i^{sz}$$
$$+ \left[G_i^1 \mu^{s1} r_i^1 /(\gamma - 1) + G_i^2 \mu^{s2} r_i^2 /(\lambda - 1)\right] + X^s(p_i^s) \tag{A13}$$

The terms are household demand, intermediate demand, demand from the construction sector, and a function $X^s(p_i^s)$ giving the value of demand for exports of each sector (i.e. sales to location 0) as a decreasing function of price. Market clearing equates this to the value supplied, as given by the production sector, equations (1) – (4).

The value of each type of labor supplied, $w_i^\ell L_i^\ell$, is equal to the value demand for labor coming from firms and from the construction sector, so

$$w_i^\ell L_i^\ell = \sum_s w_i^\ell L_i^{\ell s} + \left[\mu^{\ell 1} G_i^1 r_i^1 /(\gamma - 1) + \mu^{\ell 2} G_i^2 r_i^2 /(\lambda - 1)\right]. \tag{A14}$$

For housing of type *h* in cell *i* the equality of demand and supply takes the form

$$h = 1: \quad L^\ell \sum_j \pi_{ij}^{\ell h} \beta^{\ell h}(w_j^\ell + m_{ij}^\ell) = G_i^h r_i^h \gamma /(\gamma - 1), \tag{A15}$$

$$h = 2: \quad L^\ell \sum_j \pi_{ij}^{\ell h} \beta^{\ell h}(w_j^\ell + m_{ij}^\ell) = G_i^h r_i^h \lambda /(\lambda - 1).$$

Rents, land allocation and city size:

There are competing demands for land, coming from commercial use by each sector (in value terms $r_i^s G_i^s$), residential use ($r_i^h G_i^h$), and the possibility that land has outside use, at rent r_0 . We work with a land allocation rule that divides the total quantity of land in each cell, $\overline{G}_i$, between competing uses according to relative bid-rents. We use a CES function, such that

$$G_i^k / \overline{G}_i = \left(\rho_i^k r_i^k\right)^\phi / \left\{r_0^\phi + \sum_k \left(\rho_i^k r_i^k\right)^\phi\right\}, \tag{A16}$$

where superscript *k* runs across alternative commercial and residential uses, *k* = *s*, *h*, and ρ_i^k is a land-use/ cell specific parameter; this can be interpreted as a tax factor, although in the benchmark case $\rho_i^k = 1$ for all *i*, *k*. Notice that this relationship has inverse,

$\rho_i^k r_i^k = \left[\left\{ r_0^\phi + \sum_k \left(\rho_i^k r_i^k\right)^\phi \right\} \frac{G_i^k}{\overline{G}_i} \right]^{1/\phi}$. The parameter φ measures the intensity of competition between different uses, and is this gets very large so the land market becomes perfect (all land going to the use with highest bid-rent). Notice that the elasticity of substitution captured by φ is the same between all pairs. To capture closer substitutability between, say, two types of residential use than one residential and one commercial, a nested CES form would be needed.

We run both closed-city and open-city versions of the model. In the open version the elasticity of population with respect to the urban-rural real per capita income differential is 1.2. This elasticity is chosen so as to accurately track the population growth rates for the city between 2011 and 2035, matching the values estimated in the Dhaka Structure Plan (Rajuk).

Calibration and simulation: Equations (1) – (16) contain 16 types of endogenous variables, and the solutions of these equations give the equilibrium of the model. Thus, given the urban geography (cell areas and the distance decay matrices), functional forms as outlined above, values of elasticities, cost and expenditure shares, and productivity and amenity parameters, the solution of the model gives values of all the endogenous variables, i.e. the locations of firms and households, their supplies and demands, and equilibrium prices, incomes, and utilities.

The calibration process works in the reverse direction. Given observations on the location of firms and households and estimates of some parameters (elasticities, input and expenditure shares and aspects of geography), calibration solves for values of the productivity parameters for each sector and each cell, A_i^s, and for amenity parameters for each household type, housing type and cell, $b_i^{\ell h}$, such that the model solution is consistent with observed values.

2. Data and Parameters

Parameters:

Firms: The elasticity of substitution in demand, (equation A1) σ^s is set to 6 for all sectors *s*. Costs (equation A5) c_i^s are a CES function of prices of land, labor, and intermediates with elasticity of substitution (same for all pairs) η^s, which is set at 0.8. Factor input parameters, $a^{ms}, a^{\ell s}, a^{zs}, a^{fs}$ are set such that the value shares of each input to production costs are:

Manufacturing: Land=11.7%, High skilled labor = 58.8%, Low skilled labor= 11.7%, Primary products = 17.6%.

Tradable-services: Land=7.1%, High skilled labor = 85.8%, Low skilled labor= 7.1%, Primary products = 0%.

Non-Tradable-services: Land=3.8%, High skilled labor = 15.4%, Low skilled labor= 50%, Primary products = 30.7%.

Construction: Construction costs (equation A9) are set with the following input shares.

Traditional sector: 20% manufacturing, 10% tradable-services, 70% non-tradable-services. Modern Sector: 50% manufacturing, 30% tradable-services, 20% non-tradable-services.

The elasticity of costs with respect to density (equation A7) is $\gamma = 2$ and the elasticity of amenity with respect to density (equation A8) is $\lambda = 4$. These parameters are based on estimates for Kenya produced by Henderson et al. (2017).

Households: Household expenditure shares (equation A10) are the same across all types, and based on estimates from a household survey: Manufacturing 20.5%: Tradable-services, 10.2%: non-tradable-services (including food) 55.2%; Housing, 14%.

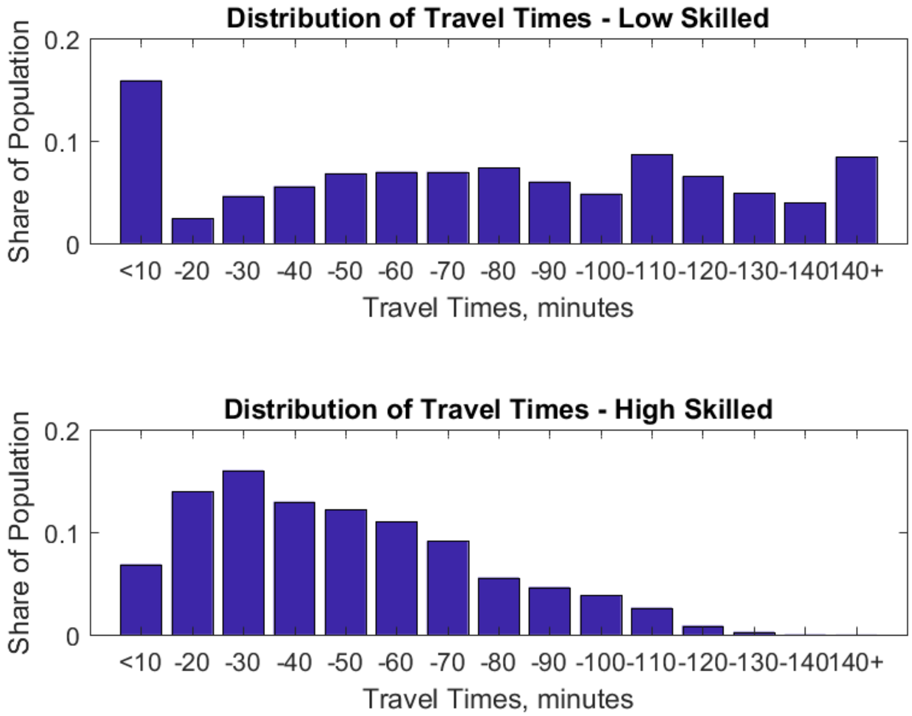
The Frechet parameter (equation A11) is $\zeta = 25$.

Transport: Transport costs within the city are highest for non-tradable-services, and lowest for tradable-services. Iceberg transport costs are modeled using exponential decay $\exp(-t * dist_{ij})$, where $dist_{ij}$ is the driving travel time between two cells i and j (normalized to 1 as the motorized driving time in the base 2011 period across the maximum distance within the city) and t is set to log(1.06) for manufacturing, log(1.05) for tradable-services, and log(1.25) for non-tradable-services.

There are no productivity spillovers between firms in the first two specifications of each scenario, however for the final specification in each scenario (e.g. Table 2 B3) with endogenous population and localization economies, these are modeled for sector s in cell i as $f^s(\sum_j \theta_{ij}^s \Lambda_j^s) = \left(\sum_j \exp(\log(0.01) * dist_{ij}) \Lambda_j^s\right)^{rs}$ where Λ_j^s is defined as the share of cell j in city-wide employment in sector s. For manufacturing and local services, the scale elasticity rs is set at zero. For tradable-services, $rs = 0.015$, ie, the returns to scale are 1.5%.

Households commuting costs are modeled similarly, with $t_{ij} = \exp(-t * dist_{ij})$ $t_{ij} = e^{\log(0.8) * dist_{ij}}$, with $dist_{ij}$ now varying as to whether individuals are high or low-skilled (driving or walking). This gives the following travel time distributions for high and low-skilled in 2011.

Figure A1 and A2 – Travel Times in Dhaka



3. Base Values and calibration

The base maps below show the true distribution of people and employment in Dhaka. In particular, the high levels of residential and employment density in Central Dhaka stand out, with a sharp reduction just a few kilometers from the CBD in neighboring East Dhaka. There is some population density in the very west portion of East Dhaka than nearest the city center, mainly living in informal housing. Both population and employment stretch along the North-South road corridor leading from the CBD, with a secondary manufacturing center to the North of Dhaka. Alongside this manufacturing zone are areas of increased population density in informal housing. Another secondary center exists to the south east, with both formal and informal housing in the surrounding areas. Tradable and Non-tradable-services both cluster in the center of the city.

Maps of Base Values – density, per km^2

Figure A3 High Skilled Population

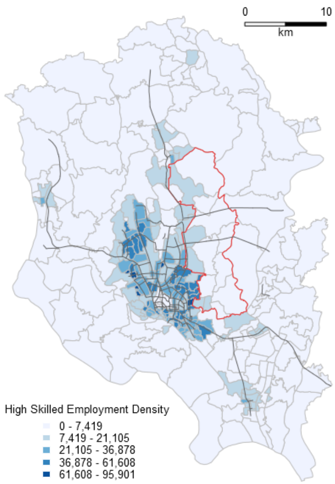


Figure A4 Low Skilled Population

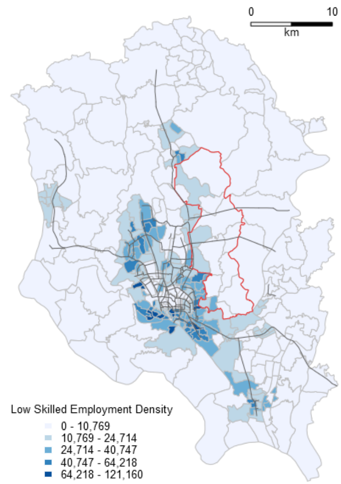


Figure A5 Formal Housing

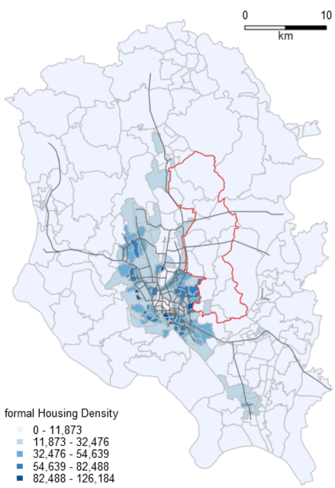


Figure A6 Informal Housing

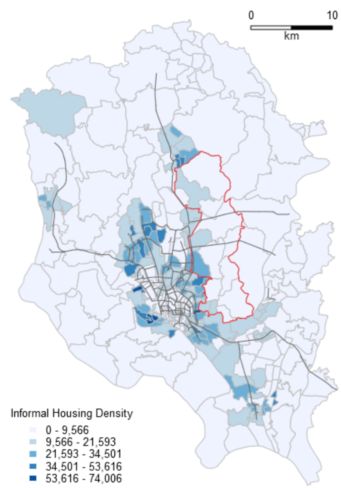


Figure A7
Manufacturing Density

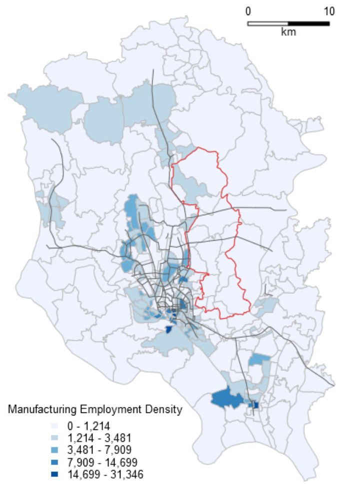


Figure A8
Tradable-services Density

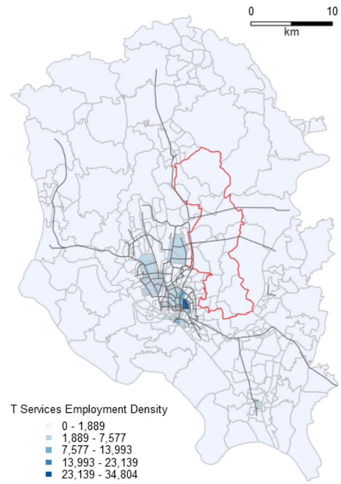
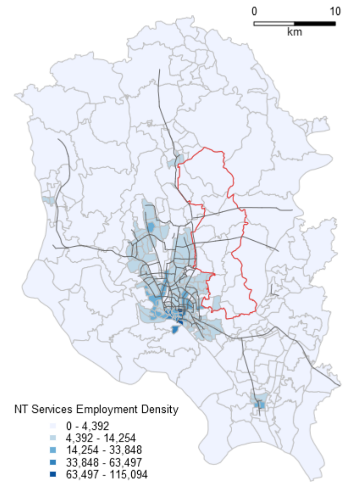


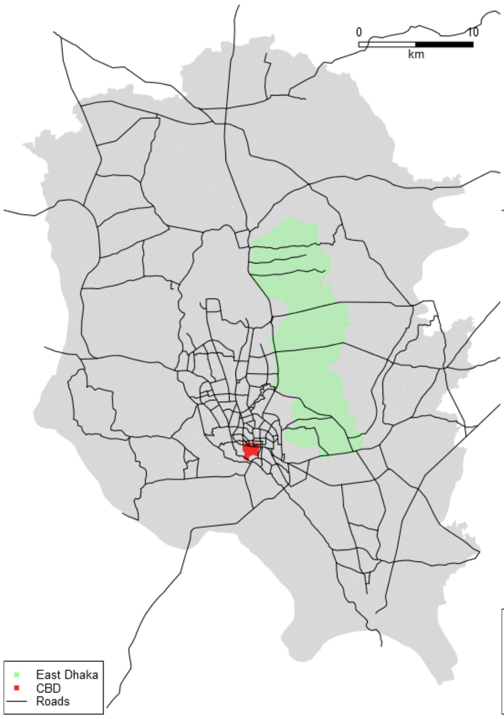
Figure A9
Non-Tradable-services Density



4. Transport Maps

Figure A10: Transport

Transport 2011



Business as Usual Transport 2035

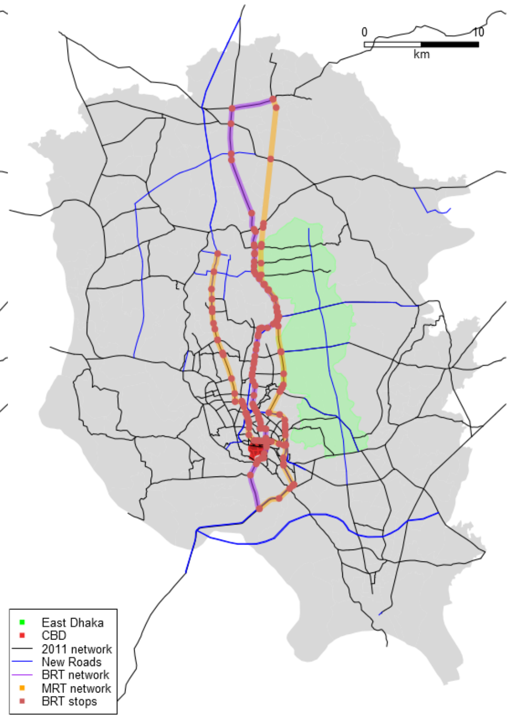
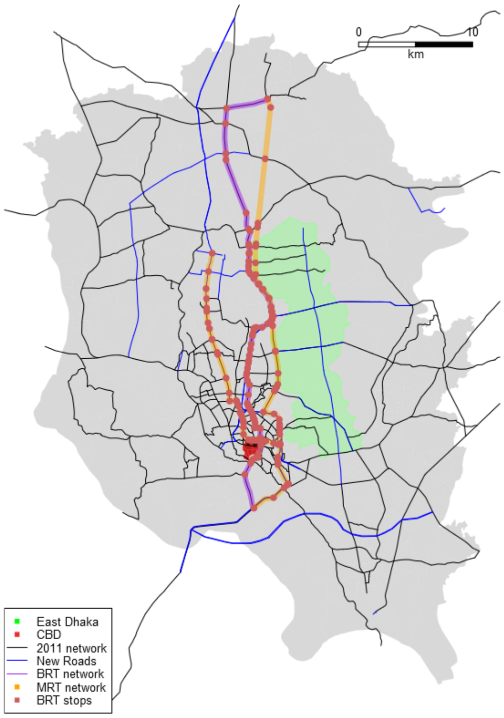
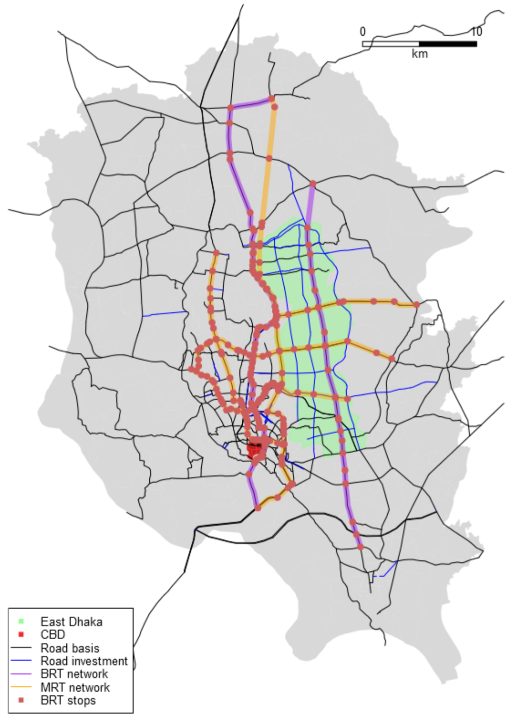


Figure A11: Transport Improvements

Business as Usual Transport 2035



Additional Transport 2035



5. Detailed Results

Table A1 : Scenario B

		Scenario A Business as Usual			1: Constant Total Population % Change from Base		
		East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population		1,566	22,993	24,559	179.1%	-12.2%	0.0%
	High Skill	580	9,519	10,099	249.5%	-15.2%	0.0%
	Low Skill	986	13,474	14,460	137.7%	-10.1%	0.0%
Employment		454	8,237	8,691	219.8%	-12.1%	0.0%
	High Skill	134	3,342	3,477	484.9%	-19.5%	0.0%
	Low Skill	320	4,895	5,215	108.7%	-7.1%	0.0%
Wage income		8,110	158,960	167,070	300.3%	-12.0%	3.2%
	High Skill	3,396	87,492	90,887	550.2%	-17.8%	3.4%
	Low Skill	4,714	71,468	76,182	120.2%	-4.9%	2.9%
Land Rent		1,833	34,461	36,294	356.8%	-16.9%	2.0%
GVA		9,702	190,291	199,993	318.4%	-13.1%	3.0%
Real Per Capita Income (Utility)				100.0			104.5
	High Skill			100.0			104.7
	Low Skill			100.0			104.3

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		2: Endogenous Population % Change from Base			3: Endogenous population and localization economies % Change from Base		
		East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population		196.6%	-7.1%	5.9%	197.7%	-6.8%	6.2%
	High Skill	271.0%	-9.9%	6.2%	272.6%	-9.6%	6.6%
	Low Skill	152.9%	-5.1%	5.7%	153.7%	-4.8%	6.0%
Employment		236.4%	-6.8%	5.9%	236.7%	-6.5%	6.2%
	High Skill	512.5%	-14.1%	6.2%	511.4%	-13.6%	6.6%
	Low Skill	120.6%	-1.8%	5.7%	121.5%	-1.6%	5.9%
Wage income		321.7%	-6.2%	9.7%	322.9%	-5.6%	10.4%
	High Skill	583.0%	-12.0%	10.3%	583.9%	-11.2%	11.1%
	Low Skill	133.6%	0.9%	9.1%	135.0%	1.3%	9.6%
Land Rent		385.4%	-11.3%	8.8%	387.0%	-11.0%	9.1%
GVA		341.7%	-7.3%	9.7%	343.0%	-6.7%	10.3%
Real Per Capita Income (Utility)				105.0			105.3
	High Skill			105.1			105.4
	Low Skill			104.7			104.9

Notes: Population and employment, thousands: income, GVA, Millions of 2015 USD.

Table A2 : Scenario C

		Scenario A Business as Usual			1: Constant Total Population % Change from Base		
		East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population		1,566	22,993	24,559	176.6%	-12.0%	0.0%
	High Skill	580	9,519	10,099	253.3%	-15.4%	0.0%
	Low Skill	986	13,474	14,460	131.5%	-9.6%	0.0%
Employment		454	8,237	8,691	229.8%	-12.7%	0.0%
	High Skill	134	3,342	3,477	472.8%	-19.0%	0.0%
	Low Skill	320	4,895	5,215	128.0%	-8.4%	0.0%
Wage income		8,110	158,960	167,070	315.6%	-9.8%	6.0%
	High Skill	3,396	87,492	90,887	551.3%	-15.3%	5.9%
	Low Skill	4,714	71,468	76,182	145.8%	-3.1%	6.1%
Land Rent		1,833	34,461	36,294	360.6%	-14.8%	4.1%
GVA		9,702	190,291	199,993	331.9%	-11.0%	5.6%
Real Per Capita Income (Utility)				100.0			107.5
	High Skill			100.0			107.6
	Low Skill			100.0			107.3

		2: Endogenous Population % Change from Base			3: Endogenous population and localization economies % Change from Base		
		East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population		207.1%	-3.4%	10.0%	214.5%	-1.4%	12.3%
	High Skill	291.7%	-6.8%	10.3%	303.0%	-4.6%	13.0%
	Low Skill	157.3%	-1.0%	9.8%	162.4%	0.8%	11.9%
Employment		259.9%	-3.8%	10.0%	265.5%	-1.6%	12.3%
	High Skill	517.7%	-10.1%	10.3%	515.7%	-7.1%	13.0%
	Low Skill	151.8%	0.5%	9.8%	160.6%	2.1%	11.8%
Wage income		354.6%	0.2%	17.4%	367.8%	4.5%	22.1%
	High Skill	607.1%	-5.2%	17.7%	619.0%	-0.1%	23.0%
	Low Skill	172.6%	6.7%	16.9%	186.8%	10.0%	21.0%
Total Rent		410.4%	-5.1%	15.9%	423.7%	-2.2%	19.3%
GVA		373.9%	-0.9%	17.3%	387.2%	3.2%	21.8%
Real Per Capita Income (Utility)				108.3			110.2
	High Skill			108.5			110.5
	Low Skill			108.0			109.6

Notes: Population and employment, thousands: income, GVA, Millions of 2015 USD.

Table A3: Scenario D – 20% cost reduction in one cell

		Scenario A Business as Usual			1: Cost of Business reduction in One Union to maximum in Central		
		East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population		1,566	22,993	24,559	281.7%	-5.2%	13.1%
	High Skill	580	9,519	10,099	433.1%	-11.5%	14.1%
	Low Skill	986	13,474	14,460	192.5%	-0.7%	12.5%
Employment		454	8,237	8,691	248.4%	0.1%	13.1%
	High Skill	134	3,342	3,477	491.0%	-5.1%	14.1%
	Low Skill	320	4,895	5,215	146.7%	3.7%	12.5%
Wage income		8,110	158,960	167,070	347.5%	6.8%	23.4%
	High Skill	3,396	87,492	90,887	590.7%	2.3%	24.3%
	Low Skill	4,714	71,468	76,182	172.3%	12.4%	22.3%
Total Rent		1,833	34,461	36,294	428.2%	-1.2%	20.5%
GVA		9,702	190,291	199,993	371.2%	5.3%	23.1%
Real Per Capita Income (Utility)				100.0			111.0
	High Skill			100.0			111.4
	Low Skill			100.0			110.0

		2: Cost of Business reduction in One Union to maximum in Central + 10%			3: Cost of Business reduction in One Union to maximum in Central + 20%		
		East Dhaka	Rest of Dhaka	All of Dhaka	East Dhaka	Rest of Dhaka	All of Dhaka
Population		271.2%	-1.4%	16.0%	284.8%	2.4%	20.4%
	High Skill	435.9%	-8.5%	17.0%	458.8%	-4.7%	21.9%
	Low Skill	174.3%	3.6%	15.2%	182.4%	7.5%	19.4%
Employment		347.5%	-2.3%	15.9%	405.3%	-0.8%	20.4%
	High Skill	830.1%	-15.6%	17.0%	987.1%	-16.9%	21.9%
	Low Skill	145.1%	6.7%	15.2%	161.3%	10.1%	19.4%
Wage income		539.1%	3.5%	29.5%	659.3%	7.4%	39.1%
	High Skill	1042.1 %	-8.7%	30.5%	1289.9%	-7.8%	40.7%
	Low Skill	176.8%	18.5%	28.3%	205.0%	26.1%	37.2%
Total Rent		525.5%	1.6%	28.1%	616.1%	6.9%	37.6%
GVA		551.2%	3.0%	29.6%	668.7%	7.2%	39.3%
Real Per Capita Income (Utility)				113.7			117.6
	High Skill			114.1			118.1
	Low Skill			112.7			116.3

Notes: Population and employment, thousands: income, GVA, Millions of 2015 USD.

6. Calibration Results

Amenity (A12-15) and productivity (A16-18) parameters for the calibrated city.

Figure A12 High Skilled Formal

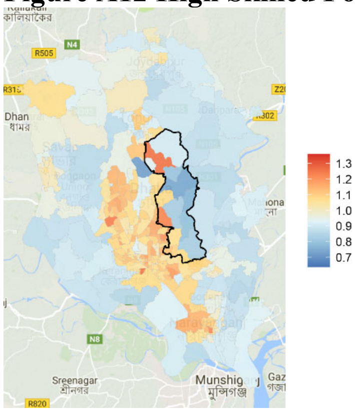

Figure A13 High Skilled Informal

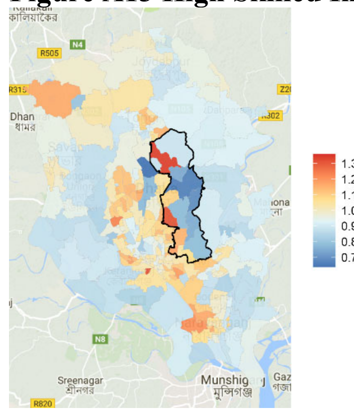

Figure A14 Low Skilled Formal

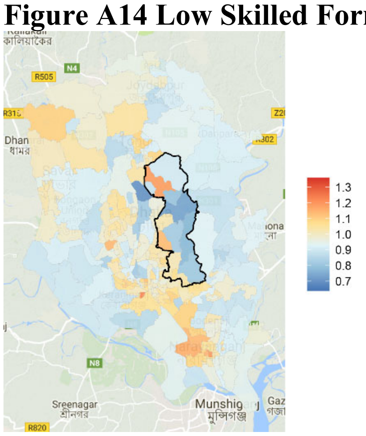

Figure A15 Low Skilled Informal

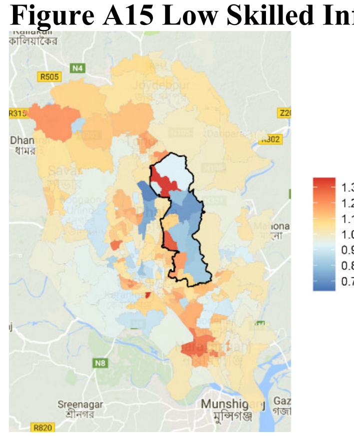

Figure A16 Manufacturing

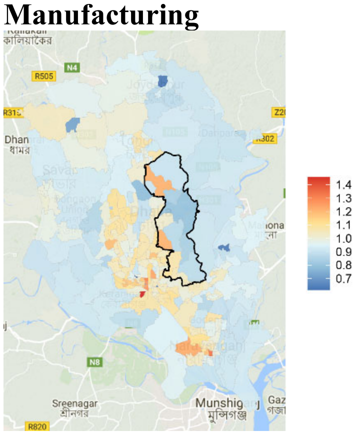

Figure A17 Tradable-services

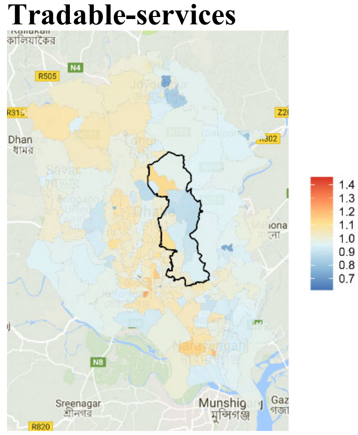

Figure A18 Non-Tradable-services