Policy Research Working Paper 8815

Assessing the Value of Market Access from Belt and Road Projects

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WORLD BANK GROUP
International Finance Corporation
April 2019

Policy Research Working Paper 8815

Abstract

The present value of market access from the Belt and Road Initiative in Eurasia does not exceed its costs. Many transportation projects are of little value because they fail to create new least-cost paths between large population centers, or because they create redundancy with paths already on the network. If built in isolation, only about one-third of projects provide market access gains. However, considering the proposed new transport infrastructure as a system, the share of projects that provide gains increases to almost two-thirds. International coordination and rigorous project selection allow mutual benefit from the investment program.

This paper is a product of the International Finance Corporation's Economics and Private Sector Development Vice Presidency. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at treed@worldbank.org and trub@uchicago.edu.

Assessing the Value of Market Access from Belt and Road Projects[1]

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Updated February 2021

JEL Classification Codes: R42, O18

Keywords: market access; transportation infrastructure; cost benefit analysis; Belt and Road

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[1] GIS shapefiles of the database of Belt and Road Initiative projects developed for this study are available here: https://github.com/sashatrubetskoy/bri_market_access. We thank Sam Asher, François de Soyres, Caroline Freund, Indermit Gil, Bert Hofman, Gabriel Kriendler, Somik Lall, Martin Melecky, Megha Mukim and Michele Ruta and participants at the Harvard Cities and Development conference for helpful comments. Robert Mwanamanga assisted with the compilation of Appendix A. The views expressed in this paper are those of the authors and do not necessarily represent those of the World Bank Group or its Directors. Correspondence to: treed@worldbank.org.

1. INTRODUCTION

The Belt and Road Initiative is the largest infrastructure construction program of the current era, but it has been officially defined only in broad terms. The initiative is described in the Chinese government's 13th Five Year Plan (Ch. 51) as an "all-around opening up in which China is opened to the world through eastward and westward links and across land and sea," a reference to previous domestic reforms initiated by Deng Xiaoping in 1978. While Deng's Open Door Policy welcomed the world into China, the Belt and Road are understood to carry the country's influence out into the world, in part by building a new network of road, rail and port infrastructure to lower trade costs between China and its neighbors. Despite ambition for mutual benefit, concerns have been raised that certain projects are not economically viable, and will leave countries burdened by debt that cannot be repaid by incremental economic growth (Hurley, Morris, and Portelance, 2018; Financial Times, 2018, 2020).

Though a literature has applied quantitative spatial equilibrium models to value transportation investments, which comprise many Belt and Road projects, these models have not yet been widely applied by policy makers in ex-ante project evaluation. Given limited transparency regarding the results of economic feasibility studies for Belt and Road projects, there is an opportunity for quantitative spatial equilibrium models to fill a gap. For this purpose, we develop an original geographic information system (GIS) database that identifies as comprehensively as possible all proposed, ongoing or recently completed road, rail and port projects along six strategic Eurasian corridors laid out in two Belt and Road strategy documents published by Chinese government agencies, and complete an ex-ante economic evaluation of these projects.[2]

This paper does not seek to push the theoretical frontier in urban economics, but rather to apply widely-accepted frameworks to study the largest and most geo-politically consequential infrastructure construction program in recent history. To our knowledge, ours is the first analysis to systematically compare the potential economic benefits of individual Belt and Road projects. Project benefits are quantified in terms of expected changes in market access—the sum of the size of all markets on the transportation network, each weighted by the inverse of the ad-valorem trade cost needed to reach it. Theoretically, increases in market access lower the cost of consumption and the cost of production in a location, leading to an increase in the value of land in a location. Total

[2] Open access GIS shapefiles of the BRI project database developed for this study are available here. These projects, whose names, locations and status (i.e., proposed, planning, under construction, operational) are listed in Appendix A, are located within 30 kilometers of at least 223 million urban residents, and span 23 different countries, which together produce 24 percent of global GDP. Excluding China, 22 countries and 9% of world GDP. Other estimates of the number of countries covered by the BRI are typically larger, as they include projects in Africa and Western Europe, which do not lie on the corridors identified in the two Chinese government documents on which we base our database. The nodes in our network include all cities described in the UN World Urbanization Prospects for 2015. Note that our database includes only transportation projects, which account for approximately 25% of BRI projects, the remainder of which comprise primarily electric energy projects, and select investments in chemicals, metallurgy and mining (World Bank, 2019). The value of non-transportation projects is outside the scope of this study.

land value generated summarizes a project's benefit. Consistent with this idea, increases in market access have been shown empirically to predict growth in population (Redding and Sturm, 2008), land values (Donaldson and Hornbeck, 2016), and night lights (Alder, 2019).

When valued according to expected changes in market access, approximately half of the 68 Belt and Road projects in Eurasia generate little benefit. Remarkably, this result holds regardless of assumptions about the economy (i.e., city income, factor shares, and the responsiveness of trade to trade costs) because projects fail to create new least-cost paths between population centers or because they create redundancy with paths already on the network. These results are validated by evidence that some projects expected to generate little market access have now been cancelled or scaled back by sponsors, and are consistent with a view that the Belt and Road program is guided by non-economic motivations. For instance, one view suggests that some default on loans associated with Belt and Road projects is desired by the Chinese government, since it would allow state-owned banks to foreclose on strategic assets, so called `debt-trap diplomacy'. An alternative explanation could be that local elites select bad projects based on their own interests (Lee and Hameiri, 2020).

Having evaluated each project individually, we ask what economic assumptions one would have to believe such that all projects built in complement are worth more than total project costs, including the cost of those projects that provide least-cost paths to nowhere. This exercise evaluates the hypothesis that optimism about economic benefits, rather than non-economic motivations, could justify the investment program. We find that such a break-even scenario obtains only with the assumption that the infrastructure program increases GDP growth in all Eurasian cities by 40 basis points, in perpetuity, beyond any static gains already accounted for by changes in market access. Such an increment to growth could be motivated by external economies of scale in urban production (see, e.g., Glaeser and Mare 2001). Though such additional growth may be plausible in certain cities nearby to projects creating large gains in market access, the existence of many individually uneconomic projects makes it less certain that such an increment to growth could be shared across all of Eurasia.

Beyond the results specific to the Belt and Road, the analysis illustrates four heuristics from the spatial equilibrium model that may be applied in transportation planning. First, projects may be complements or substitutes. If built in isolation, only about one-third of projects provide market access gains. Considering the proposed new transport infrastructure as a system, however, the share of projects that provide gains increases to almost two-thirds. Conversely, a small number of projects become less valuable when the rest of the network is built, as other links make the projects redundant.

Second, reforms that increase factor mobility across locations are likely to be complementary to investments in physical transportation infrastructure, though quantitatively they appear moderate. We simulate a counterfactual in which Eurasian Belt and Road countries become an economic union with free internal factor mobility, along the lines of the United States. In this case, aggregate value created by all projects built in complement is 8 percent larger than under a scenario in which factors are immobile.

Third, the same transportation network improvement is worth more in a richer country. This is due to a level effect in which improvements in market access are worth more in larger (i.e., richer or more populous) markets. To the extent that project costs are determined by prices of internationally traded materials and capital equipment rather than local land and labor costs, this implies any given transportation project is less likely to be economically feasible when it is located is in a poorer country. This observation may partially rationalize limited investment in infrastructure in low-income countries as an equilibrium market outcome and explain why poor countries struggle to finance infrastructure through taxation of incremental income, leading to recurrent challenges with national debt.

Fourth, some projects, especially those affecting sea routes, generate external benefits far from their location. While the cities experiencing the greatest gains in market access are frequently those located close to the projects, the greatest gains in welfare accrue to China and western Europe. This suggests that infrastructure built in low- and middle-income countries along international trade corridors is a public good for which high income countries should be willing to pay.

Our work is related to a substantial literature quantifying the economic impact of between-city transportation investment programs ex-post.[3] The market access approach has been used to study railroads in the 19th century United States (Donaldson and Hornbeck, 2016; Hornbeck and Rotemberg, 2020), and more recently highways in India (Alder, 2019) and Brazil (Morten and Olivera, 2018). Others have used alternative research designs to study highways in China (Faber, 2014) and India (Ghani, Goswami, and Kerr, 2016), railways in Africa (Jedwab and Moradi, 2016) and ports and highways in Africa (Storeygard, 2016). Asher and Novosad (2019) find that the Prime Minister's Village Road Program (PMGSY) in India provided little measurable economic benefit for households. The market access framework provides an economic rationale for this finding: since the size (and purchasing power) of the rural markets is not large, there is

[3] A distinct literature studies the impact of within-city transportation investments, for instance radial highways and rail surrounding cities in China (Baum-Snow, Brandt, Henderson, Turner, and Zhang, 2017), a bus rapid transit system in Bogota, Colombia (Tsivanidis, 2019) and the steam railroad in 19th century London (Redding, Sturm, and Heblich, 2020).

little value in lowering the cost of trade between them. We build on these studies by applying the market access approach to evaluate port, rail, and road investments ex-ante while accounting for asymmetric trade costs between locations, a feature of the international transportation network, where tariffs are generally levied on imports but not exports. Existing applications assume trade costs are symmetric. Others have used variants of the equilibrium model employed here to conduct ex-ante economic evaluations of improvements to the road network in Africa (Buys, Deichmann, and Wheeler 2010), the United States (Allen and Arkolakis 2019), and Western Europe (Fajgelbaum and Schaal 2020). The general question of how to value the so-called "wider economic benefits" of transportation projects beyond direct benefits for users has been addressed by Venables (2017) and Melecky, Bougna, and Xu (2018) among others.

Alternative estimates of the economic impact of the Belt and Road Initiative are based on our original GIS database of transportation projects (De Soyres, et al., 2018, De Soyres, Mulabdic, and Ruta., 2019; Maliszewska and Van Der Mensbrugghe, 2019; Lall and Lebrand, 2019; World Bank, 2019). These studies evaluate the Belt and Road as a single bundle of projects built in complement, rather than evaluating individual projects.

2. A GIS DATABASE OF BELT AND ROAD TRANSPORTATION PROJECTS

This paper provides an original and comprehensive database of all existing and planned transportation infrastructure projects proposed under the Belt and Road Initiative. Our database is unique in that it includes geographical information describing the exact location of each project (i.e., in GIS shapefiles) on the international transportation network.[4] This geographical information serves as the basis for our analysis of the projects' welfare impact.

Projects are included in our database if they lie physically along Belt and Road routes defined by two official Chinese sources (Office of the Leading Group for the Belt and Road Initiative, 2017; Government of China, 2017) and if they are mentioned in one of the following sources as being part of BRI: (i) a document issued by a government or its press agency, (ii) an article in a major academic journal or global news source, or (iii) a quote by a government official in a global or leading national news source. Sources reviewed include joint declarations by China and Belt and Road

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[4] Four other databases of Belt and Road projects exist. The Reconnecting Asia database by the Center for Strategic and International Studies (CSIS), the China Global Investment Tracker by the American Enterprise Institute (AEI), the MERICS Belt and Road Tracker, and the Hong Kong Trade Development Council (HKDTC) database. The CSIS database is a broad database covering 152 BRI-related transportation projects in Eastern Europe and Asia and overlaps substantially with ours, though does not include detailed GIS files that overlay these projects onto the transportation network. The database is notable for including some (but not complete) information on project costs. The AEI database emphasizes capital flows associated with certain projects, covering 50 investments related to road, rail or shipping infrastructure. The MERICS Belt and Road Tracker includes ample discussion of policy related to the BRI but does not offer a specific database of projects accessible to researchers. The database by HKDTC has a very broad scope that extends beyond transport links. It does list 106 logistics-related projects, most of which are not directly related to transport infrastructure.

countries, statements issued by government agencies (e.g., ministries, legislatures) of individual countries, global news organizations (e.g., Financial Times, Reuters), local news sources in which government officials are quoted, industry journals, and think tank publications. Projects need not be financed by Chinese banks to be included. Given this approach, our database uses a consistent set of criteria to include projects and is comprehensive within those criteria.

Office of the Leading Group for the Belt and Road Initiative (2017, pg. 9) describes the overall geographic scope of the Belt and Road succinctly: "Based on the proposal from President Xi and the need to promote international cooperation and taking into consideration the routes of the ancient land and sea Silk Roads, China has determined five routes for the Belt and Road. The Silk Road Economic Belt has three routes: one from Northwest China and Northeast China to Europe and the Baltic Sea via Central Asia and the Russian Federation; one from Northwest China to the Persian Gulf and the Mediterranean Sea, passing through Central Asia and West Asia; and one from Southwest China through the Indochina Peninsula to the Indian Ocean. The 21st-Century Maritime Silk Road has two major routes: one starts from coastal ports of China, crosses the South China Sea, passes through the Malacca Strait, and reaches the Indian Ocean, extending to Europe; the other starts from coastal ports of China, crosses the South China Sea, and extends to the South Pacific." Note a source of potential confusion is that the "Belt" refers to the overland routes, where many of the projects are road improvements, whereas the "Road" refers to the maritime routes, where projects are primarily ports. Further, note that though Africa may be discussed by some as being part of the Belt and Road initiative given substantial Chinese investment on the continent, it is not included explicitly in these corridors.

Appendix A describes the 93 improvements to the transportation network included in our database and their status, as well as references to the sources used to include them. Of these improvements, 67 are on the Silk Road Economic Belt and 26 are on the Maritime Silk Road. These improvements are subsequently grouped into 75 projects when they are described jointly in our sources (for instance, the Sihanoukville Port project consists of three improvements: a port, a road, and a railway). In Table A1, Belt projects are grouped along six land corridors described by Office of the Leading Group for the Belt and Road Initiative (2017) and in Table A2, the Road projects are grouped along three sea passages described by the Government of China (2017). Table A1 includes a few examples of African rail projects that were attributed to the BRI by alternative sources, though Africa is not included in these corridors. In our analysis of welfare impacts, we will focus on the 68 projects from the Belt and Road that are in Eurasia. Figure 1 shows these projects.

These 68 projects are overlaid on the existing network of all major rail, road and port infrastructure in Asia, Europe and the Middle East (i.e., Eurasia), beginning with existing road and rail connections documented in Natural Earth (Kelso and Patterson, 2018). In cases where Natural Earth does not include connections between cities, we include on the network additional road connections from OpenStreetMap. In China, rail data are further supplemented using Li's high-speed railway shapefiles (Harvard Dataverse, 2016). Ports included on this network are those handling more than 5 million twenty-foot equivalent units (TEU) in 2015 (Nightingale, 2016). TEU is an inexact unit of cargo capacity used in the shipping industry, corresponding to the volume of a 20-foot-long intermodal container. Sea links between ports are derived by assuming ships can take the most direct feasible route between ports. To our best understanding, the resulting transportation network includes all major highways, railroads and ports in Eurasia.

Finally, we identify population and land with nodes on the network using the 964 cities nearest (i.e., within 30 kilometers) to any link with the transportation network, when all 68 projects are built in complement. Populations of these cities are as reported for 2015 by the UN Urbanization Prospects. In the average country, cities on the network comprise 24 percent of total population, though there is a range, with Singapore 97 percent, Turkey at 49 percent, and Cambodia at 11 percent, reflecting variation in domestic connectivity and urbanization in these countries, as well as the geographic scope of the Belt and Road itself. As shown in Figure 1, the Belt and Road passes through only portions of many countries. Our baseline specification focuses on welfare gains accruing only to these cities with direct connectivity to the international network. In discussion of the results however, we consider the implication of allocating additional population and land (e.g., from rural areas, or greater metropolitan areas around cities) to the nodes on the network.

3. THE MARKET ACCESS APPROACH TO VALUING THE BENEFITS OF IMPROVEMENTS TO AN INTERNATIONAL TRANSPORTATION NETWORK

The market access approach to quantify the welfare benefit of a transportation investment is elaborated by Donaldson and Hornbeck (2016) for the case of a domestic transportation network. Here, we focus on how to interpret the model in the context of an international transportation network, and the specific modifications we make to their model in order to apply the framework to the Belt and Road. The central mechanism in the model through which transportation investment affects welfare is price adjustment--- when investment causes trade costs to decline between cities, consumers and firms in each city can buy goods more cheaply.

To set up the model, index locations on the transportation network by $o = 1, \dots, O$. The model is built on three assumptions about these locations. The first is that they share a Cobb-Douglas (constant returns) technology to produce goods with land, labor and capital. The share of local income Y_o that is paid to land is given by α, the share paid to labor by β, and the share paid to capital by $1 - \alpha - \beta$. The second assumption is a neoclassical gravity model of trade, with constant elasticity of substitution preferences for varieties produced by each location, in which the elasticity of trade flows to trade costs is given by the ratio $1/\theta$, where $\theta > 1$ (Eaton and Kortum, 2002; Head and Meyer, 2014; Adao, Costinot, and Donaldson, 2017). The third is a spatial equilibrium in which factors are mobile across space and the marginal product of capital and utility (i.e., the real, local-price-adjusted, wage) are equalized across locations (Glaeser, 2008).

In an international trade model, while the assumption of a common technology and trade elasticity are standard, the spatial equilibrium is a strong assumption. While there is substantial labor and capital mobility within subsets of Eurasian countries, facilitated for instance by the economic integration agreements underlying the Association of Southeast Asian Nations and the European Union, mobility within the entire continent is clearly constrained. In the analysis we value market access under two alternative scenarios of international integration (among a variety of other alternative specifications). In the baseline scenario, local income Y_o is held fixed in all cities to simulate the case in which there is no factor mobility, as in standard international trade analysis. In the alternative scenario, we use Theorem 1 of Allen and Arkolakis (2014) to calculate what income would be in each city if factors were able to freely reallocate in response to the change in trade costs induced by the Belt and Road projects, simulating a world in which the Belt and Road network of cities is a perfectly integrated economic union. The difference between the gains from Belt and Road projects under these two scenarios describes the additional (complementary) benefit of implementing international integration agreements alongside Belt and Road projects.

To calculate benefits from a change in trade costs induced by a project, the model requires calibration of three parameters and baseline income Y_o in each city. In our baseline specification, we use $\alpha = 0.05$, the land share of income in the (urban) non-agricultural sector (Valentinyi and Herrendorf, 2008); $\beta = 0.65$, a lower bound estimate for the labor share in developing countries (Gollin, 2002); and $\theta = 5$, a standard value of the trade elasticity (Head and Mayer, 2014).

Under the three assumptions above, the price of land—the immobile factor of production—is a log-linear function of a location's market access. In each location o,

$$\ln(\mathrm{r}_o) = \kappa + \left(\frac{1}{1+\alpha\theta}\right)(\ln(FMA_o) + \beta\ln(CMA_o)) + \varepsilon_o \qquad (1)$$

where r_o is the annual rental rate of land, κ is a constant and ε_o is an error term that is increasing in the city's underlying absolute productivity advantage and decreasing in the abundance of land.[5] The term FMA_o is 'firm market access', and the term CMA_o is 'consumer market access.' These terms are producer and consumer prices that summarize the value of all distant markets given the costs of trading with them. When these prices change in a city, the value accrues to owners of the immobile factor of production.

[5] This corresponds to equation 6 in Donaldson and Hornbeck (2016).

We work with first-order approximations[6] of these prices, which are functions only of market size and trade costs,

$$FMA_o \approx \sum_d \left(\frac{1}{\tau_{od}}\right)^{\theta} Y_d$$

$$CMA_d \approx \sum_o \left(\frac{1}{\tau_{od}}\right)^{\theta} Y_o$$

where trade costs between market o and d $\tau_{od} > 1$ are ad-valorem, taking the standard "iceberg" form. The mechanism through which transportation investments affect welfare is by changing in trade costs, which increase market access, and therefore land prices.[7] We proceed to describe the measurement of trade costs, and then how they are expected to be affected by Belt and Road projects.

Prior applications of this model to a domestic transportation network (e.g., Morten and Olivera 2018; Alder 2019) typically assume that $\tau_{od} = \tau_{do}$, which implies equality of CMA_o and FMA_o up to a constant. This assumption is not appropriate on an international transportation network, since tariffs are an important component of trade

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[6] The exact values of firm and consumer market access in the model are defined by equations 7 and 8 in Donaldson and Hornbeck (2016), $FMA_o \equiv \sum_d \tau_{od}{}^{-\theta} CMA_d^{-1} Y_d$ and $CMA_d \equiv \sum_o \tau_{od}{}^{-\theta} FMA_o^{-1} Y_o$, a system of $O \times 2$ equations that can be solved numerically. We find that the (logs of) the exact values and (logs of) the first-order approximations are highly correlated.

[7] In the background, the volume of trade will also increase as trade costs fall, increasing utilization of the transportation corridor. Appendix C reports the closed form equations for trade flows.

costs, and are generally levied on imports but not exports. Relaxing the symmetry assumption, we define ad-valorem trade costs when shipping from origin city o to destination city d as $\tau_{od} \equiv$

$$1 + \begin{cases} \frac{1}{S}\sum_{j=1}^{|J|} \hat{c}^j d_{od}^j, & k(o) = k(d) \\ \frac{1}{S}\left[\sum_{j=1}^{|J|} \hat{c}^j d_{od}^j + border_{k(o)}^{export} + border_{k(d)}^{import}\right] + \ tariff_{k(d)}^{import}, & k(o) \neq k(d) \end{cases}$$

where countries are indexed by k; $\hat{c}^j$ is an estimate of the freight rate per unit of distance for each road, rail, or sea link segment j reflecting the labor, fuel, maintenance and depreciation costs of freight transport; d_{od}^j is distance; and the set of segments J is chosen such that it minimizes the trade cost $\hat{\tau}_{od}$.[8]

When cities are in the same country and $k(o) = k(d)$ the interpretation of ad-valorem trade costs is straightforward: transport costs are the sum of transport costs along each segment, divided by the value of the shipment. We set $S = \$50{,}000$ or the notional value of a shipment provided to survey respondents who quote border costs to the World Bank's Doing Business Indicators. Border and tariff costs are added only when the origin and destination are in different countries, or when $k(o) \neq k(d)$. For country k, $border_k^{export}$ refers to the sum of quoted export border and documentary compliance costs and $border_k^{import}$ refers to the sum of quoted import border and documentary compliance costs, all from the Doing Business Indicators. The average ad-

[8] The selection of the minimum cost route is performed using the shortest_path function in the NetworkX package, which makes use of Dijkstra's (1959) algorithm.

valorem tariff in the importing country $tariff_k^{import}$ is observed in the World Development Indicators as the average applied tariff rate over all products, weighted by the value of products imported (this value is highly correlated with the simple average of tariffs across products). Border and tariff costs are applied only at the origin and destination, consistent with the fact that most countries on the network are signatories to the TIR (*Transports Internationaux Routiers*) convention, which allows swift and low-cost movement of transit trade trucks across border. Rail and port facilities typically also have expedited processes for transit goods.

In addition to these ad-valorem trade costs, we allow for two additional costs along the network: mode-switching costs and (port) terminal handling charges. Mode-switching costs reflect the hassle of changing transport modes, so that the least-cost path does not switch modes an unreasonable number of times. Formally, when calculating trade costs $\hat{\tau}_{od}$ we replace the term $\sum_{j=1}^{|J|} \hat{c}^j d_{od}^j$ with

$$\sum_{j=1}^{|J|} 25 \times I\left[switch^j\right] + \hat{c}^j d_{od}^j$$

where $I\left[switch^j\right]$ is an indicator for whether the trip on segment j, in the direction from o to d, ends by connecting to a different mode (either rail to road, or road to rail). This effectively adds a \$25 switching fee for each container. This fee is selected so that it is small compared to terminal handling charges, which are incurred when a shipment passes through a port. Herrera Dappe and Suárez-Alemán (2016) report that on our network these costs range between \$65/TEU in Chennai, India to \$268/TEU in Rotterdam, Netherlands. To also include terminal handing charges in trade costs, we replace the term $\sum_{j=1}^{|J|} \hat{c}^j d_{od}^j$ in the definition of trade costs $\hat{\tau}_{od}$ with

$$\sum_{j=1}^{|J|} 200 \times I\left[port^j\right] + \hat{c}^j d_{od}^j$$

where $I[port^i]$ is an indicator for whether the trip from o to d along segment i ends at a port, effectively adding a $200 terminal handling charge for each port the container passes through. The value of mode-switching and terminal handling charges are very small relative to the value of a shipment (i.e., 0.13–0.54 percent with a shipment value of $50,000/TEU).

We set freight rates $\hat{c}^j$ equal to those quoted along the network. Table 1 reports a range of quotes, by mode, measured in US dollars per twenty-foot-equivalent unit (TEU) per kilometer. Looking at the median upper and lower bound quotes by mode across references yields the well-known cost ranking in which sea is the cheapest mode (at $0.04 TEU/KM), rail is the next cheapest mode ($0.23-$0.47 TEU/KM) and road is the most expensive mode ($0.63-$0.85 TEU/KM). For regular road and rail segments (e.g., single carriageway), we set the freight rate equal to the median of the upper bound estimates in Table 1, a more expensive rate. For high capacity road and rail, we set the freight rate equal to the median of the lower bound estimates, a less expensive rate. This captures the idea that upgrades to higher capacity lowers costs. For sea, we use a single freight rate equal to the median estimate of the sea freight rate across all studies (the very high upper bound estimates for sea trade presented in Table 1 correspond to very short distances, due to the high fixed costs of sea travel, and so does not apply generally).

A Belt and Road project is modeled as a change in the vector of trade costs from $\tau = \{\tau_{od}\}$ to $\tau' = \{\tau'_{od}\}$, leading to a change in market access. We can write this change as

$$\widehat{FMA}_o \equiv FMA'_o / FMA_o$$

$$\widehat{CMA}_o \equiv CMA'_o / CMA_o$$

where the numerator in each expression indicates the value of market access evaluated when substituting τ' in place of τ. Table 2 shows how specific improvements to the network are recorded as changes in trade cost, using several examples from the Belt and

Road. These examples demonstrate the order of magnitude of the expected changes in freight rates that can be expected from the Belt and Road. For instance, the road upgrade of Highway A2 connecting Kazakhstan to Uzbekistan implies a change from regular to high capacity, and so with the assumptions above, suggests a decrease in the freight rate on that road segment from \$0.85 to \$0.63. Here, we have modeled expected increases in speed (due to increased capacity) as reductions in costs, though part of this cost reduction will also come from reductions in vehicle operating costs. The Belt and Road may also build new links between two cities. For instance the Tehran-Isfahan high speed rail will add a route with a freight rate equal \$0.23, where one did not exist before.

We close by describing how the model is used to put a dollar value on market access from Belt and Road projects. Equation (1) allows us to write

$$\ln(r'_o) - \ln(r_o) = \left(\frac{1}{1+\alpha\theta}\right)\ln\left(\widehat{MA}_o\right) \tag{2}$$

where

$$\ln\left(\widehat{MA}_i\right) \equiv \ln\left(\widehat{FMA}_o\right) + \beta \times \ln\left(\widehat{CMA}_o\right)$$

In this derivation, we have assumed no congestion or agglomeration externalities—besides the change in market access, a project has no other effect on the city's absolute productivity advantage (i.e., $\varepsilon'_i - \varepsilon_i = 0$).[9] Let the quantity of land in a city be given by L_o. Since the technology is Cobb-Douglas, we can define annual payments to land in

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[9] We subsequently relax the assumption of no economies of scale in Section 4. The present assumption also assumes that the project has a negligible effect on the supply of land.

the city as $V_o \equiv L_o r_o = \alpha Y_o$. Taking the exponent of equation (2) and combining it with the definition of payments to land allows us to define

$$V_o' \equiv L_o\, r_o' = L_o\, r_o' \frac{r_o}{r_o'} = \alpha Y_o \left(\widehat{MA}_o\right)^{\frac{1}{1+\alpha\theta}}.$$

The total additional land value generated is therefore given by

$$\Delta V_o \equiv V_o' - V_o = \alpha Y_o \left[\left(\widehat{MA}_o\right)^{\frac{1}{1+\alpha\theta}} - 1\right] \qquad (3)$$

and the total value created across all cities is given by

$$\Delta V \equiv \alpha \sum_o Y_o \left[\left(\widehat{MA}_o\right)^{\frac{1}{1+\alpha\theta}} - 1\right]. \qquad (4)$$

Equation (3) describes the (dollar) value of changes in market access in each individual city. Equation (4) summarizes the total value of changes in market access across the entire network.

It is straightforward to use equation (4) for the benefit-cost analysis of any transportation project. The annuity or present value of the project's benefits is given by

$$PVB \equiv \Delta V(1+g)/(\rho - g) \qquad (5)$$

where ρ is the discount rate and g is the GDP growth rate. The present value of construction and maintenance costs may be compared to the present value of project benefits. If benefits are larger than costs, the project is worthwhile.

What remains to undertake the analysis is a measure of income in each city (at the numeraire price), or Y_o. Since most countries do not maintain national accounts disaggregated at the city level, especially within our large sample of countries, we evaluate Equation (4) under several alternatives. Our baseline measure is simply city population times national GDP per capita. Given the range of countries in our sample, from high-income Denmark to low-income Tajikistan, this assumption captures much of the relevant variation in income across cities. However, within countries, this assumption may underestimate GDP in major metropolitan areas that are richer than the national average, or alternatively overestimate income in more remote cities. Therefore, in a second specification we replace our baseline estimate of income where possible with an estimate of city GDP from Oxford Economics, a research service that prepares forecasts. As expected, these estimates in some cases are lower than the national average, and in some cases are higher, with the average city GDP being 2.3 times larger using the alternative measure. Compared to variation across countries in national GDP per capita, this alternative specification does not appear to have a large effect on city income. In a third specification, we allocate all national income to cities on the network, in proportion to their relative populations (i.e., so a city with 20 percent of the population has 20 percent of GDP). This specification is comparable to what would be obtained by a country-level analysis that treats projects as a shock to international trade costs, while assuming a country's entire land and population is affected similarly by reductions in trade costs (see, e.g., De Soyres, Mulabdic and Ruta 2019).

4. RESULTS

4.1 Trade on the Eurasian transportation network

Several cross-country results will be familiar to readers in international trade, and provide assurance that the gravity model (the second of our model's three key assumptions) is appropriate in our context when using the specification of trade costs described above. In Figure 2, Panel (a) shows China's 2017 exports to all countries in the sample, and (b) shows imports, both as reported by COMTRADE since comprehensive data on trade and traffic flows between cities are not available. In the top chart of each panel, the horizontal axes of both figures show the GDP of the trading partner. Trade flows and GDP are in log terms and normalized by dividing by the corresponding value for Portugal. Both have a positive slope and show substantial fit: $R^2 = 0.64$ for exports and $R^2 = 0.65$ for imports. The bottom chart in each panel displays on the horizontal axis our measure of trade costs. Though both charts show a negative slope, the fit in these lower panels is not as high as in the upper panels ($R^2 = 0.03$ for exports and $R^2 = 0.11$ for imports), though it is larger for imports, where tariffs contribute disproportionately to overall trade costs. These results suggest we can apply the market access approach in our context, since though it has the advantage of not requiring data on trade or traffic flows, it does require that trade conforms to the gravity relationship.

4.2 Baseline market access

To describe the economy before the Belt and Road projects, we report baseline levels of (log) market access in each city, $\ln(MA_o) = \ln(FMA_o) + \beta \ln(CMA_o)$, where firm and consumer market access are calculated separately using asymmetric trade costs. Table 3 reports the largest city in each decile of baseline market access, for each of the World Bank's groupings of national income, as well as the share of cities in each decile that are located near a port, border or the national capital.

Some of the results may be counterintuitive. First, while market access is correlated with national income, the correlation is not perfect. In the lowest three deciles of market access there are no cities in high income countries. In the top four deciles there are no cities with low income. Similarly, we see that some of the largest cities in India (Delhi, Mumbai and Chennai) all have relatively low market access relative to some of the largest cities in China (Shanghai and Guangzhou) which have higher per capita income. National income is not everything however; relatively high-income cities in smaller countries, such as Stockholm, Sweden, and Lisbon, Portugal, have lower market access than large cities in China, where the larger population of neighboring cities compensates for their relatively lower per capita income.

Second, though connectivity to ports appears related to market access, proximity to a border need not be. Twelve percent of cities in the top decile are port cities, compared to 0-6 percent in all other deciles. This result is likely due to the large difference between sea freight rates ($0.04/TEU/KM) versus low capacity rail ($0.47) and road ($0.85). Looking at border cities, a substantial share of the population in the lowest decile of market access, 16 percent, is concentrated in border cities, but the same share of the top decile is also concentrated in border cities. Connectivity at the border does not necessarily increase market access, unless it also offers a link to substantially lower freight rates, which is only the case for a sea border. Being a capital does not seem systematically associated with market access.

4.3 The value of changes in market access from individual Belt and Road projects

We now value the expected changes in market access from building each of the 68 Belt and Road projects in Eurasia, using the correspondence between project type and change in trade costs in Table 3. We evaluate each project under two scenarios: (i) "in isolation", in which no Belt and Road projects have been built, and (ii) "in complement", in which all Belt and Road projects have been built except P. The comparison of these scenarios is informative about the extent to there is value from coordinated planning of projects. In this initial analysis, we hold Y_o fixed at its baseline value, considering a world without complementary economic integration reforms, and apply the baseline specification of parameter values and income described in Section 3.

Figure 2 shows this result of the analysis visually, mapping the (log) changes in market access in each city in Eurasia for the scenario in which each project is built in complement.[10] Notably, some of the largest gains in market access are outside China, in

[10] A question is whether the ranking of cities by changes in market access are stable to alternative specifications of the model. If the ranking is stable, this suggests that

lower income countries, for instance Kyrgyzstan and the Lao People's Democratic Republic. Market access gains in Europe appear small, which is not surprising given the distance of Europe from most projects. Overall, this map suggests that the Belt and Road projects do have the potential to improve market access for some cities, especially in lower income countries.

Equation (3) converts changes in market access at the city level into units of welfare, yielding the value of market access in terms of income to land (ΔV_i). Figure 3 show these values on a map, a very different picture from Figure 2. When represented in terms of incremental land value, the largest gains now appear in higher income cities of Europe. Large cities in China also have larger gains. This result stems from the fact that these cities have larger base levels of income, and so the same increase in market access generates much more benefit in rich markets than in markets that are poor. The comparison of these two maps highlights a useful heuristic for the cost benefit analysis of transportation projects. Since the value of gains in market access are a multiple of local income, the total value of project benefits will be smaller in poorer countries.

Table 4 reports the distribution of annual benefits ΔV generated by each project. For each project, the value of additional market access is disaggregated using Equation (3), to show the share of benefits accruing to the country in which the project is built (except

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the gravity model makes generalizable predictions about the location of benefits associated with a given project. To assess this question, Appendix Table B1 reports the Spearman (rank) correlation of changes in market access across cities for a variety of alternative specifications. Overall, the results show that the model's rankings of cities are remarkably stable, with rank correlations in the range of 0.7–1.0 across specifications.

China), and the share accruing to China itself. This disaggregation allows one to evaluate the extent to which the BRI may be motivated by the national interest of China, or magnanimity towards other nations. An equal split of project benefits between China and other countries is consistent with the idea that there is potential for "mutual benefit" from the projects, as claimed in Chinese government sources.

This analysis delivers three key results. First, while some projects do appear to produce substantial benefit, more than half of all projects do not generate any benefit. The maximum annual benefit of a project (ΔV) when built insolation is just \$750 million, or \$1.45 billion, in present value terms with $\rho = 0.06$ and a perpetual GDP growth rate of $g = 0.055$. This value drops off quickly however, with the 75th percentile project generating just \$8.3 million per annum when built in isolation, or \$16 million in present value, and the 50th percentile project yielding benefits equal to zero.

This result suggests that many Belt and Road projects should not be expected to generate incremental income. We note that this result obtains because many projects do not create new least-cost paths between any city pair on the transportation network, and therefore fail to change market access regardless of the model's calibrated parameters α, β, θ, and Y_o. Though in the following subsection we explore robustness of our estimates to alternative specifications of these parameters, our main conclusion that many projects do not generate increases in market access is robust to these alternative specifications. Moreover, benefits of these projects will fail to exceed project costs for any estimate of costs.

Table 5 provides some examples of projects that do and do not produce benefits. Projects in the table are grouped by terciles of estimated project value (ΔV). Several projects in the top tercile are those connecting major population areas. For example, the Tehran-Mashhad rail electrification connects two of the Islamic Republic of Iran's largest urban agglomerations. The Kunming-Calcutta High Speed Rail is also expected to produce substantial benefits, mainly by linking poorly connected large cities in

Bangladesh. The ML-1 railway in Pakistan also connects the country's major cities. This observation is consistent with the finding of Allen and Arkolakis (2019), also using a gravity model, that the most valuable highway improvements in the United States are along the heavily trafficked corridors of the north-east near large cities including New York.

Turning to the middle tercile of our valuations, which includes projects with $\Delta V = 0$, we see that governments have indeed scaled back projects. Specifically, the East Coast Rail Link (Malaysia) was suspended and then renegotiated at 1/3 lower cost. The Kyaupyu Port (Myanmar) was recently scaled down from 10 berths to 2 berths. These results provide some external validation of the model's predictions.

Our second result is that there appears to be substantial complementarity between projects. When projects are built in isolation, just 29 have value above zero, whereas when the projects are built in complement, 43 have positive value. This suggests that 14 projects only become valuable when the whole network is built. Perhaps surprisingly, some projects are more valuable when built in isolation. We see this in cases where the ratio $\Delta V_{iso.} / \Delta V_{comp.} > 1$. The project with the highest ratio is 192 times more valuable when built in isolation, suggesting it is possible for redundant projects to erase the benefits of a project. When ranked by this ratio, the 90th percentile project is 4.2 times more valuable in isolation. Certain projects therefore may cannibalize each other's traffic (along the least-cost path) when built concurrently. Examples of such projects include the Bangkok-Pedang Besar-Kuala Lumpur rail (Thailand, Malaysia) and the Burma Railway (Myanmar, Thailand). Taken together, these findings indicate there are returns to targeted inquiry into redundancy between projects.

Our third result is that gains from some projects are shared internationally with countries quite far from their location, demonstrating that infrastructure investment can be an international public good. Considering projects when built in complement, the 90th percentile of projects with $\Delta V > 0$ has 43 percent of the value accruing to a country (besides China) that the project is not located in. The 75th percentile has 21 percent of the value accruing to such countries. These international gains are slightly more common when projects are built in isolation. When projects are built in isolation, 38 percent of the gains accrue to China for the median project, even though projects are located outside of China.

Overall, our results are consistent with the Chinese government's stated understanding of the Belt and Road as generating "mutual benefit" for China and other countries (Office of the Leading Group […], 2017, pg. 4). Perhaps surprisingly, substantial gains accrue to European countries that do not lie along Belt and Road corridors, but nonetheless benefit from reduced trade costs along the international transportation network. However, the results also demonstrate that many projects cannot be justified on a purely economic basis, consistent with China (and project sponsoring countries) have non-economic motivations in promoting the projects. International coordination of investment can improve the economic returns to the program of investment, but these additional benefits will come from cancelling at least one third of the projects.

4.4 Sensitivity of results to alternative specifications

Though some projects fail to produce economic benefits in terms of market access, it could be that the benefits of some projects are so large that they could compensate for the construction cost of the projects that do not increase market access. In this scenario, Belt and Road countries in principle could redistribute income amongst themselves to pay for the bad projects. We explore the feasibility of this scenario in this subsection by evaluating the benefits of projects when built in complement under a diverse set of alternative specifications, which represent the different ways in which the analyst could choose to be optimistic about the project.

Total benefits are compared to an independent estimate of cost by De Soyres, Mulabdic and Ruta (2019), who estimate the cost of transportation projects as a function of mode and length, using our GIS database and country-specific cost information collected from World Bank country offices, which finance transportation infrastructure in the region and so has references for such projects. For all countries in Eurasia, these authors estimate the cost of all projects built in complement to be approximately $321 billion.[11]

Table 6 reports the value of market access from each of the six Eurasian corridors when each corridor is built separately, and the value when all six corridors are built in complement. The columns of the table report these values under a variety of specifications, beginning with the baseline specification described in Section 3. The three panels of Table 6 show how the present value of benefits is built up using Equation (5). They are shown separately to illustrate the sensitivity of the estimates to the discount rate and growth rate, a standard issue in financial analysis. Panel A reports the annual value of market access (ΔV) implied by Equation (4). Panel B reports the present value of these benefits assuming a discount rate $\rho = 0.06$ and $g = 0$, indicating zero GDP growth. This discount rate is generously low (leading to an optimistic estimate of project benefits) for two reasons. First it is only in the lower range of the central bank policy rate in Belt and Road countries (e.g., Pakistan, Laos). Many other countries face a higher opportunity cost of funds. Second, since loans to finance infrastructure have longer tenure than short government loans, the discount rate applied to evaluating infrastructure investments is likely to be higher than even the central bank

[11] Actual project costs are not available because, as described in the Introduction, governments in general have not been transparent about the financing of Belt and Road projects.

policy rate in any country. The relatively low rate selected here may be understood therefore to capture some preference for the welfare of future generations, in addition to the cost of capital. Panel C provides in our assessment a reasonable, if slightly optimistic basis for evaluating benefits, assuming $\rho = 0.06$ and a perpetual GDP growth rate of $g = 0.055$, the growth rate for developing Europe and Asia in 2019 (IMF, 2020). Comparing results in panels A, B and C illustrates the substantial degrees of freedom available in an analysis of the present value of a project's benefits.

Focusing on the results in panel C, the present value of all projects when built in complement in our baseline specification is just \$87.9 billion, far less than the independently estimated costs of \$321 billion. Looking at an individual corridor, the value of the China-Pakistan Economic corridor is just \$3.7 billion, far less than project costs in Pakistan alone of \$49 billion according to De Soyres, Mulabdic and Ruta (2019). We now review the implications of alternative specifications.

First, we investigate alternative values of the model's three fundamental parameters. Equation (4) shows that scaling the parameter α will increase one-to-one the expected benefit of the project. Valentinyi and Herrendorf (2008) show that across non-agricultural (urban) sectors this share varies little, from a minimum of $\alpha = 0.03$ in construction and equipment investment to a maximum of $\alpha = 0.06$ in services. Applying the value for services would increase benefits relative to our baseline specification by 0.06/0.05 = 1.2 or a 20 percent increase in benefits, to \$105.4 billion, still far less than \$321 billion. While a higher share of income to the fixed factor could feasibly obtain in some extremely dense urban centers, it would be optimistic to assume it is everywhere in all cities triple the estimate for the service sector.

Setting the labor share $\beta = 0$ corresponds to the case where consumer market access does not matter, only the value of the market to firms. As expected, benefits are reduced substantially. Increasing the labor share to $\beta = 0.8$ corresponds to an upper bound estimate of the labor share in developing countries (Gollin, 2002), which leads to benefits in Panel C of $96 billion when all projects built in complement, only slightly higher than the baseline.

One hypothesis is that our single sector model ignores the fact that transportation investments may be especially beneficial to specific sectors. Using data on trade flows in North America, Caliendo and Parro (2015) find an aggregate elasticity of trade to trade costs $\theta = 4.55$, close our baseline value, though they also find that θ can vary by sector. The value $\theta = 2$ is a theoretical minimum (if the variance of the Type-II extreme value distribution underlying city productivity in the model is to be finite; see Donaldson and Hornbeck, 2016). Caliendo and Parro (2015) estimate elasticities in agriculture ($\theta = 8.11$) and mining ($\theta = 15.72$) implying these sectors offer a higher sensitivity of trade to trade cost than in aggregate. Alternative columns of Table 6 consider project benefits as if all trade was in these sectors. While project values are lower with $\theta = 2$, they are almost double the result of the baseline specification when we set $\theta = 15.72$. Nonetheless, the value of all projects in Panel C even under this specification is still just $170 billion, approximately half of costs. Allowing a very high sensitivity of trade to trade costs therefore may increase gains from individual projects but does not lead the present value of benefits from all projects to exceed their costs.

We turn to alternative specifications of income. First, we use alternative estimates of city GDP from the research service Oxford economics, as described in Section 3. These alternative values of city GDP lead to an estimate in Panel C of the present value of project benefits equal to $140.6 billion, 60 percent more than the baseline specification, but still less than half of project costs. Second, we use alternative estimates of city GDP that assume all of countries' income is allocated to the nodes on the network. Here the present value of project benefits in Panel C is $272.2 billion, which is 309 percent of the baseline estimate, but still less than estimated projects costs. Even under the assumption therefore that within country trade costs are zero off of the international transportation network, and that the value of all land in the country will increase identically in response to improvements to that network, the present value of the Belt and Road projects built in complement does not exceed their costs.

We now consider would happen if the Belt and Road were complemented by international integration reforms that freed labor and capital to reallocate optimally across the transportation network. So far, in our calculation of ΔV we have assumed that after trade costs fall, the income of each city remains constant (before adjusting for firm and consumer price changes). To relax this assumption, we apply Theorem 1 of Allen and Arkolakis (2014), which states that the vector of city income Y_o in this model's equilibrium is a unique fixed point, determined by trade costs. Using an iterative algorithm described in Appendix C we calculate the market size of each city under post-BRI trade costs if factors can optimally reallocate, holding each city's total factor productivity fixed at baseline levels. Allowing for factor reallocation in this way leads to an improvement over our baseline specification, with the present value of benefits in Panel C equal to \$95 billion, or 9 more more than the baseline specification. International integration agreements can therefore be complementary to transportation infrastructure, but in this case are not pivotal in determining whether benefits are greater than costs.

This discussion has demonstrated how allowing alternative specifications of the main parameters α, β, θ, and Y_o as well as perfect factor mobility does not change the conclusion all Belt and Road projects, when built in complement, do not create gains in market access that exceed their costs.

A final argument we consider is that the program can break even, but only if, in addition to lowering production costs, reductions in trade costs allow cities to capture scale economies in urban production, or so-called `agglomeration' economies (see, e.g., Duranton and Puga, 2004). These gains must be in addition to reductions in traffic congestion costs already accounted for by the fact that road and rail capacity expansions to deliver lower trade costs. In the baseline version of the model with no factor mobility, such economies would be hard to justify, since there only prices change, not the scale of production in each city. However, such benefits could obtain in the specification with increased factor mobility, where the scale of production in cities in certain cities may increase. One potential mechanism for increased economies of scale through this channel could be that migration of workers to larger cities allows them to accumulate human capital more quickly (Glaeser and Mare, 2001), which would accelerate the growth rate of the economy.

Setting the present value of benefits in Equation (5) equal to the estimated costs of \$321 billion and rearranging allows one to back out how much additional growth through this mechanism would be required to break even. Using the same discount rate $\rho = 0.06$ and the value of annual benefits $\Delta V = \$452$ million from the specification of the model in Table 6 that includes factor reallocation, this calculation yields a required growth rate of $g = 0.059$ for the program of all 68 projects built in complement to break even, or 40 basis points in additional annual GDP growth---in perpetuity---for all cities in Eurasia as a result of the program.

This calculation highlights how in benefit-cost analysis the terminal growth rate of benefits is an extremely important parameter.[12] For the complete program of Belt and Road projects to be justified on purely economic grounds, one must accept that it accelerates economic growth throughout Eurasia substantially, in addition to the static gains highlighted by the spatial equilibrium model in Section 3. Whether such gains are plausible is an active area of research in urban economics, though estimating the magnitude of agglomeration economies is notoriously difficult. Some recent descriptive work calls into question the potential for a substantial economic growth multiplier. Using both panel

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[12] The key robustness table in almost any financial valuation analysis explores sensitivity to the terminal growth rate and the discount rate.

and instrumental variable econometric methods, Frick and Rodríguez-Pose (2016) find that while in high-income countries average city size and GDP per capita growth are positively related, in developing countries this relationship is insignificant or negative. This finding suggests that while the Glaeser and Mare (2001) mechanism for dynamic agglomeration gains exists in the United States, it may escape developing countries where most Belt and Road projects are located. One explanation for this could be that higher congestion within cities not directly addressed by Belt and Road projects, which mainly connect cities, makes it more difficult for workers to learn from one another, eliminating the effect of increased density on human capital accumulation. This conjecture is plausible, having sat in traffic in Beijing or Lahore.

5. CONCLUDING REMARKS

This paper finds find that the present value of increased market access from all planned, on-going and completed Belt and Road transportation projects in Eurasia is very likely to be less than these projects' costs. This conclusion stems from the fact that approximately one-third of projects do not create new least cost paths on the network, even when all projects are built in complement. Nonetheless, subsets of the investments could be economically viable. If benefits of the entire Belt and Road program are to be greater than costs, this will be due to either a much narrower set of projects being selected than the set proposed by officials, or the presence of external economies of scale leading to a substantial increase in the *growth rate* for all Belt and Road economies. Whether such dynamic gains from transportation investments are feasible, especially in low- and middle-income economies, is an important question that warrants future research.

Beyond the Belt and Road, the analysis has demonstrated several general heuristics that policy-makers can use to evaluate transportation projects: (i) projects may be substitutes or complements in reducing costs on the network, (ii) reforms that allow the reallocation of factors in response to the project can increase benefits, though this effect appears moderate; (iii) benefits will be higher in richer countries all else equal, since project benefits are a multiple of national income, suggesting poorer countries in general may struggle to fund infrastructure; and (iv) transportation infrastructure can be an international public good that creates benefits far from its location.

Taken together, our findings do suggest the Belt and Road has the potential to create substantial mutual benefit for China and countries along the Eurasian transportation network. However, to achieve this, rigorous economic feasibility analysis is required, and some projects must be cancelled, as is already happening in select markets.

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TABLES

Table 1: Estimates of transport costs, USD/TEU/kilometer

	ROAD		RAIL			SEA	
	Lower bound	Upper bound	Lower bound	Upper bound		Lower bound	Upper bound
EMERSON (2009)	-	-	0.47	0.47		0.07	0.73
RODEMANN (2014)	0.66	0.78	0.39	0.53		-	-
SEO (2017)	0.52	0.54	0.23	0.45		0.03	0.04
SLADKOWSKI (2015)	0.6	1.78	0.23	0.56		0.04	0.7
SUN (2017)	0.84	0.92	0.14	0.25		-	-
MEDIAN	*0.63*	*0.85*	*0.23*	*0.47*			*0.04*

Table References

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Table 2: Representation of BRI projects by change in freight rates

Improvement Type (see Appendix A)	Description	Example BRI project	Representation by change in fright rate parameters (see Table 2)	FREIGHT RATE *(USD/TEU/KM)* PRE-BRI	POST-BRI
New road	A new undivided highway is built.	• M3/M4 Multan Highway (Pakistan) • Highway AH4 (Russian Federation, Mongolia, China)	Does not Exist (DNE) → Road	-	0.85
New divided road	A new divided highway (dual carriageway or 4-lane road with median) or expressway is built.	• Urumqi-Khorgos road (China) • Khorgos-Almaty road (Kazakhstan)	DNE → High capacity road	-	0.63
Road upgrade	An undivided road is upgraded to an expressway or divided highway.	• Highway A2: Almaty-Tashkent (Kazakhstan, Uzbekistan) • Highway A3 (Kazakhstan)	Road → High capacity road	0.85	0.63
Road reconstruction	Road was existing, but unsuitable for commercial traffic. Road is upgraded to a modern undivided highway.	• Jalalabad–Töö Ashuu (Kyrgyz Republic) • Kashgar–Khunerjab (China)	DNE → Road	-	0.85
New rail	A new unelectrified one-track rail connection is built.	• Khorgos-Aktau Railway (Kazakhstan)	DNE → Rail	-	0.47
New high capacity rail	A new electrified and/or dual-track trail connection is built. May be for high speed passenger traffic ("high-speed rail"), but not necessarily.	• Tehran-Isfahan high speed rail (Iran, Islamic Rep.) • Kunming-Calcutta high-speed rail (China, Myanmar, Bangladesh, India)	DNE → High capacity rail	-	0.23
Rail upgrade	One-track rail line is expanded to two tracks or electrified.	• Karachi-Peshawar capacity expansion (Pakistan) • Samarkand-Mashhad rail (Uzbekistan, Turkmenistan, Iran, Islamic Rep.)	Rail → High capacity rail	0.47	0.23
Rail reconstruction	Rail connected was existing, but antiquated or unsuitable for modern locomotives. Rail is upgraded to a modern single-track connection.	• Erdent-Salkhit (Mongolia) • Chifeng–Jinzhou (China)	DNE → Rail	-	0.47

New seaport	A seaport is significantly expanded (capacity at least doubled) or newly built	• Hambantota Port (Sri Lanka) • Gwadar Port (Pakistan)	New sea links added	-	0.04
New sea link	A new shipping service is established between two existing ports.	• Ankalia port (Georgia) • Turkmenbashi–Baku (Turkmenistan, Azerbaijan)	New sea links added	-	0.04

Table 3: City summary statistics by decile of baseline market access (MA)

Initial MA decile	Median ln(MA)	Largest city by income group: Lower Middle	Upper Middle	High	Population (2015): Total	Median across cities	CAGR, 2005–2015	UN Forecast CAGR, 2015–2030	GDP (2015): Total	Per capita median across cities	% capital cities	% port cities	% pop in border cities
					Mn. People	*Thou. people*			*Bn. USD*	*USD*			
1st	29.63	Dhaka	Tehran	*none*	136	547	2.7%	2.4%	364	1,651	10%	3%	16%
2nd	29.73	Delhi	Baku	*none*	114	580	2.7%	2.4%	237	1,758	3%	0%	3%
3rd	29.76	Mumbai	Bangkok	*none*	146	584	2.6%	2.3%	362	1,758	0%	1%	1%
4th	29.81	Chennai	Kuala Lumpur	Athens	93	565	1.8%	1.5%	951	11,325	12%	4%	2%
5th	29.85	Kharkiv	Istanbul	Stockholm	93	561	1.8%	1.2%	1,044	6,497	8%	1%	4%
6th	29.86	Kiev	Chongqing	Lisbon	112	619	2.7%	2.0%	936	6,497	6%	4%	1%
7th	29.87	*none*	Beijing	Warsaw	110	576	2.7%	1.9%	828	6,497	3%	6%	1%
8th	29.88	*none*	Shenyang	Budapest	101	732	3.0%	2.3%	723	6,497	4%	2%	3%
9th	29.88	*none*	Guangzhou	Madrid	162	892	2.9%	2.0%	1,760	6,497	6%	6%	1%
10th	29.90	*none*	Shanghai	Paris	149	638	1.4%	1.1%	4,818	41,642	9%	12%	16%

Notes*:* Each decile has 96 cities, except the 1st and 10th, which have 97 cities each. GDP figures use constant 2010 US dollars.

Table 4: The value of market access from individual Belt and Road projects

	Units	Project-level summary statistics							
			Percentile						Number of
		Min	*10*	*25*	*50*	*75*	*90*	*Max*	projects
A) Projects built in isolation									
Annual Project Value (ΔV)	$ millions	0.0	0.0	0.0	0.0	8.3	32.9	750.0	68
Share of ΔV in proj. country (besides China), if ΔV>0	percent	0.0	0.0	0.0	5.0	50.0	58.3	66.0	29
Share of ΔV in China, if ΔV>0	percent	0.0	9.7	13.0	38.0	38.0	42.6	55.0	29
B) Projects built in complement									
Annual Project Value (ΔV)	$ millions	0.0	0.0	0.0	4.0	15.3	42.2	744.0	68
Share of ΔV in proj. country (besides China), if ΔV>0	percent	0.0	0.0	0.0	0.5	21.3	43.2	57.0	43
Share of ΔV in China, if ΔV>0	percent	0.0	0.0	0.0	1.0	9.3	21.3	47.0	43
Ratio of ΔV iso./ΔV comp.		0.0	0.0	0.0	0.0	0.9	4.2	191.6	68

Note: Table shows the distributions of individual BRI project values when built under two scenarios: (A) in isolation, wherein network on which the project is built does not include any other Belt and Road projects, and (B) in complement, wherein all other projects are assumed to be built before the project is built. Additional rows also show the share of project value either outside the project country or in China.

Table 5: Status of select projects and estimated value of market access

Project	Est. ΔV in isolation	Status of project	Discussion
Thai Canal Thailand	Top tercile	Proposed, but no studies conducted. Project declared not a priority by Thai government.	The canal would bypass Singapore and shorten shipping by 1,000 km, costing 20-30 Bn USD. Canal area currently faces religious insurgency. Thailand only sees 1% of ΔV, and ΔV is significantly lower in complement with other projects. ΔV is much lower if the cost of sea travel is lowered from 0.05 to 0.01 USD per km.
Kunming-Calcutta High Speed Rail, Bangladesh, India, Myanmar	Top tercile	Chinese officials have expressed support, but concrete planning has not begun.	The market access gains from this project would come from connecting cities in Bangladesh that currently have poor infrastructure. This assumes, of course, that the rail is also used for freight. Since most of the 2,000-kilometer railway will bring no benefit, concrete steps are not being taken. Projects specific to Bangladesh are being promoted instead.
Tehran-Mashhad rail electrification, Islamic Republic of Iran	Top tercile	Studies finalized in 2018. Construction set to begin in 2019.	This electrification project will enhance the rail link between two of the Islamic Republic of Iran's largest urban agglomerations. The high market access increase is also due in part to the Islamic Republic of Iran's relatively high GDP per capita.
Expansion of railway Line ML-1, Pakistan	Top tercile	Phase 1 of construction initiated in 2018. Expected completion 2022.	ML-1 is Pakistan's most important rail line, linking the key cities of Karachi, Hyderabad, Lahore and Peshawar. Upgrades to this line will greatly increase market access for Pakistan's large cities, which are near but have poor transport links.
Kuantan Port, Malaysia	Top tercile	Completed in 2018.	The expansion of Kuantan Port creates new shipping links between Malaysia and other Southeast Asian countries. Reduced transport costs increase market access in Kuantan and Kuala Lumpur, whose relatively high GDP per capita translate to a large increase in land rents.
Bangkok-Vientiane rail, Thailand and Laos	Middle tercile	Thailand portion of railway is being built and will open in 2021.	This railway will connect large and higher-income Bangkok with areas of northeast Thailand and Laos that were poorly connected prior to BRI, increasing market access for cities in those areas.
East Coast Rail Link, Malaysia	Middle tercile	Work suspended but resumed after negotiation of 1/3 cost reduction.	The railway would not link any major population centers, while access to shipping lanes would see only very slight improvement. Budget cut from RM 66.7 Bn to RM 44 Bn. Cancellation would have incurred a termination fee of RM21.8 Bn ($5.3 Bn).

Kyaukpyu Port, Myanmar	Middle tercile	Port project scaled down from 10 berths to 2 berths.	The port did not create any new routes that are sufficiently low in cost to generate any increases in land rents.

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Table 6: The value of market access from Belt and Road projects when built in complement

US$ Millions	Model Specification: Base-line	Labor share β=0	Labor share β=0.8	θ=2, lower bound	θ=8.1, agri-culture	θ=15.7, mining	Oxford Econ. GDP	National Population	With factor realloc-ation	Min.	Max.
Panel A) Annual benefits --- ΔV											
China-Indochina Peninsula Economic Corridor	273	167	297	125	384	547	442	832	292	125	832
New Eurasian Land Bridge	34	21	37	16	47	65	56	105	37	16	105
China-Central Asia-West Asia Economic Corridor	26	15	28	12	35	47	38	78	28	12	78
Bangladesh-China-India-Myanmar Economic	28	16	30	14	36	44	46	89	31	14	89
China-Mongolia-Russia Economic Corridor	24	14	26	11	33	47	42	65	26	11	65
China-Pakistan Economic Corridor	18	10	19	9	23	28	22	59	20	9	59
All Projects Built in Complement	417	251	455	194	579	806	667	1,290	452	194	1,290
Panel B) Present value of benefits with 6% discount rate, 0% growth --- ΔV/0.06											
China-Indochina Peninsula Economic Corridor	4,548	2,776	4,957	2,088	6,401	9,121	7,371	13,867	4,874	2,088	832
New Eurasian Land Bridge	568	347	619	268	781	1,075	930	1,750	616	268	105
China-Central Asia-West Asia Economic Corridor	428	250	469	206	579	790	634	1,300	466	206	78
Bangladesh-China-India-Myanmar Economic	460	260	506	225	607	741	762	1,483	510	225	89
China-Mongolia-Russia Economic Corridor	392	241	427	179	553	789	693	1,083	428	179	65
China-Pakistan Economic Corridor	293	161	323	145	385	470	368	983	328	145	59
All Projects Built in Complement	6,951	4,180	7,591	3,240	9,654	13,433	11,114	21,500	7,531	3,240	1,290
Panel C) Present value of benefits with 6% discount rate, 5.5% growth --- (ΔV*1.055)/(0.06-0.055)											
China-Indochina Peninsula Economic Corridor	57,582	35,150	62,761	26,435	81,038	115,474	93,312	175,552	61,708	26,435	832
New Eurasian Land Bridge	7,195	4,397	7,841	3,399	9,889	13,610	11,773	22,155	7,794	3,399	105
China-Central Asia-West Asia Economic Corridor	5,414	3,164	5,934	2,614	7,332	9,996	8,029	16,458	5,897	2,614	78
Bangladesh-China-India-Myanmar Economic	5,821	3,292	6,404	2,849	7,680	9,378	9,649	18,779	6,455	2,849	89
China-Mongolia-Russia Economic Corridor	4,962	3,054	5,402	2,270	6,998	9,990	8,775	13,715	5,416	2,270	65
China-Pakistan Economic Corridor	3,706	2,037	4,091	1,835	4,869	5,950	4,657	12,449	4,159	1,835	59
All Projects Built in Complement	87,999	52,924	96,096	41,024	122,218	170,056	140,699	272,190	95,345	41,024	1,290

FIGURES

Figure 1: Map of BRI improvements in Eurasia

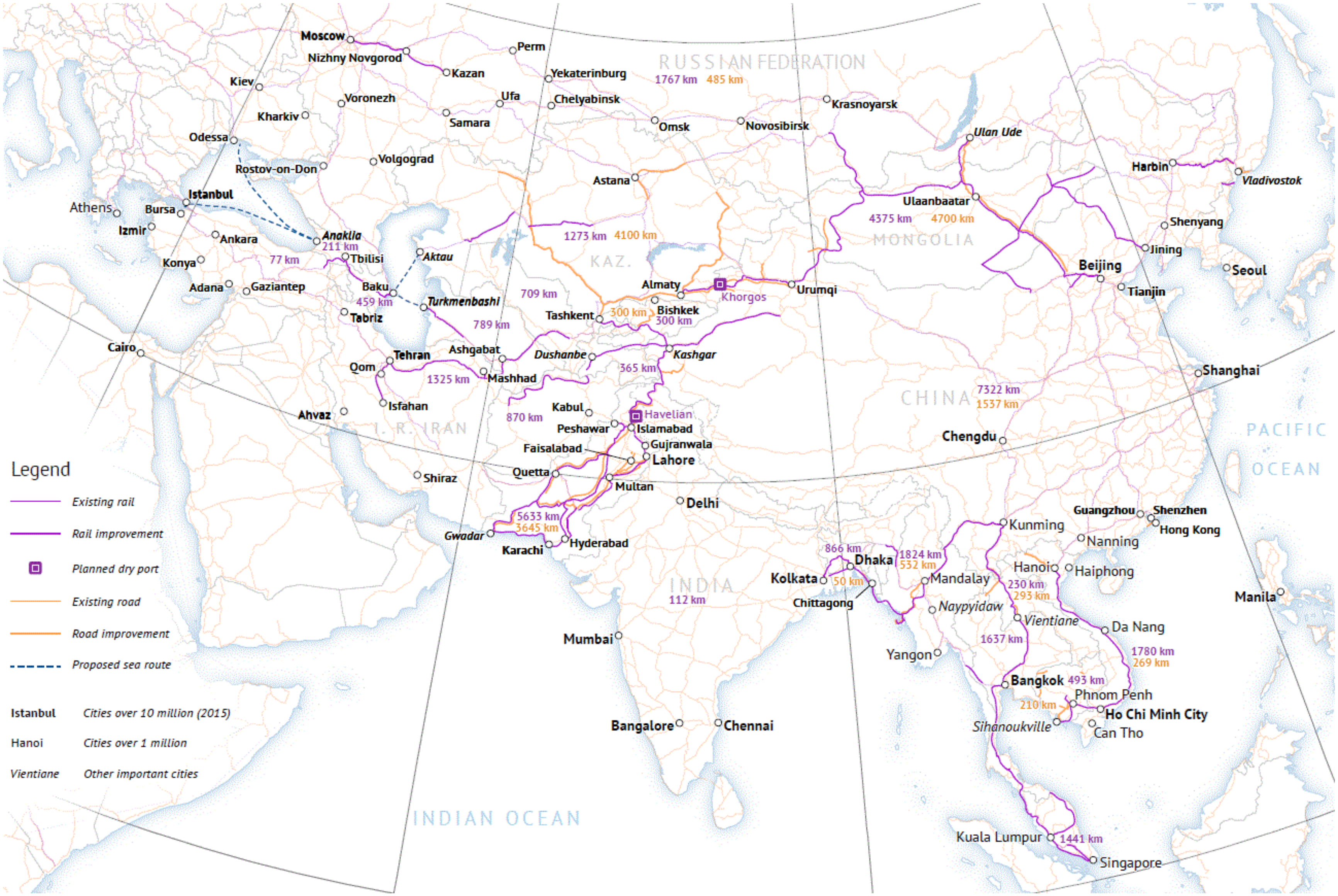


Figure 2: International trade flows in Eurasia fit the gravity relationship

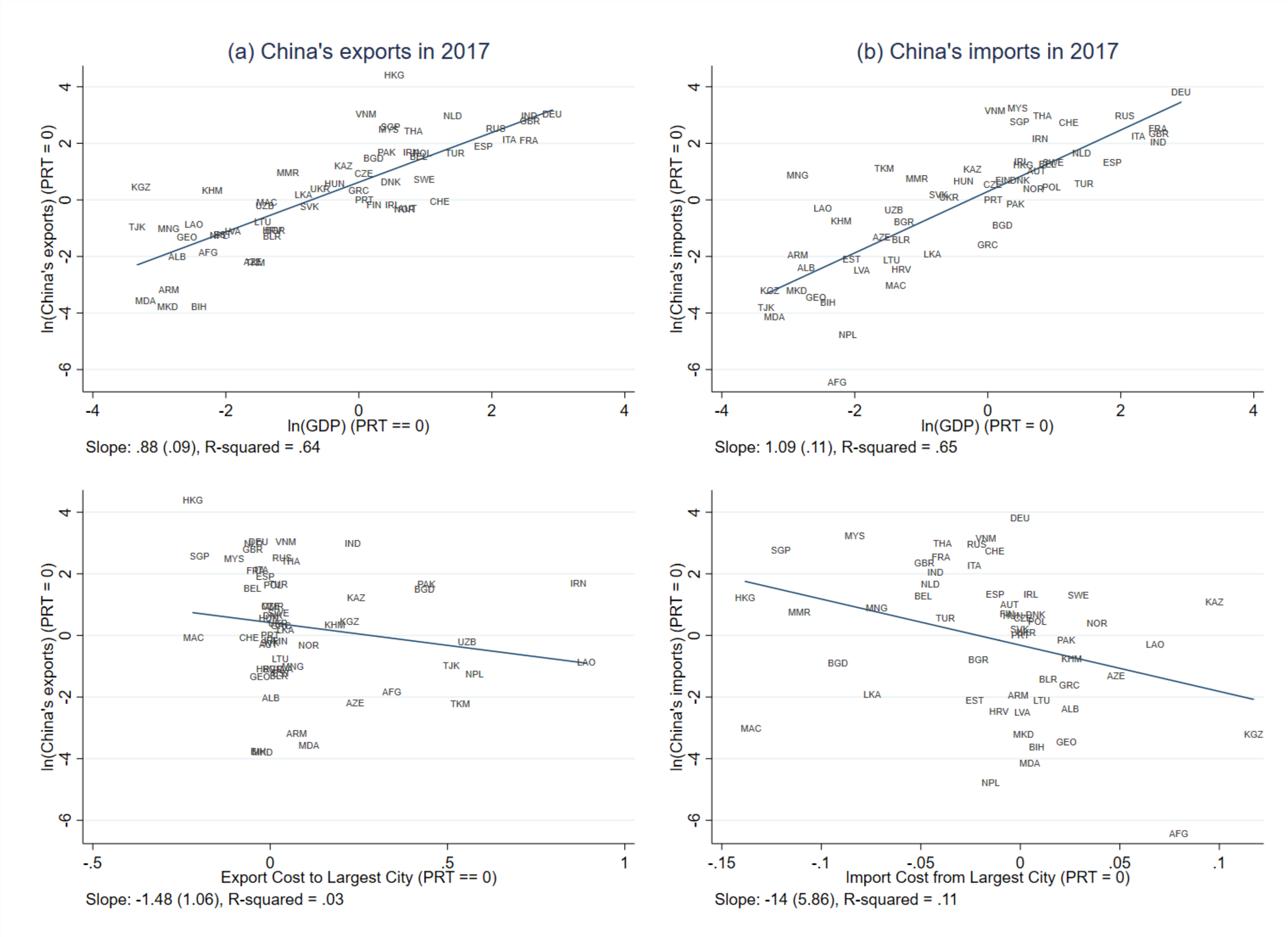


Figure 2: Changes in market access when all BRI projects are built in complement

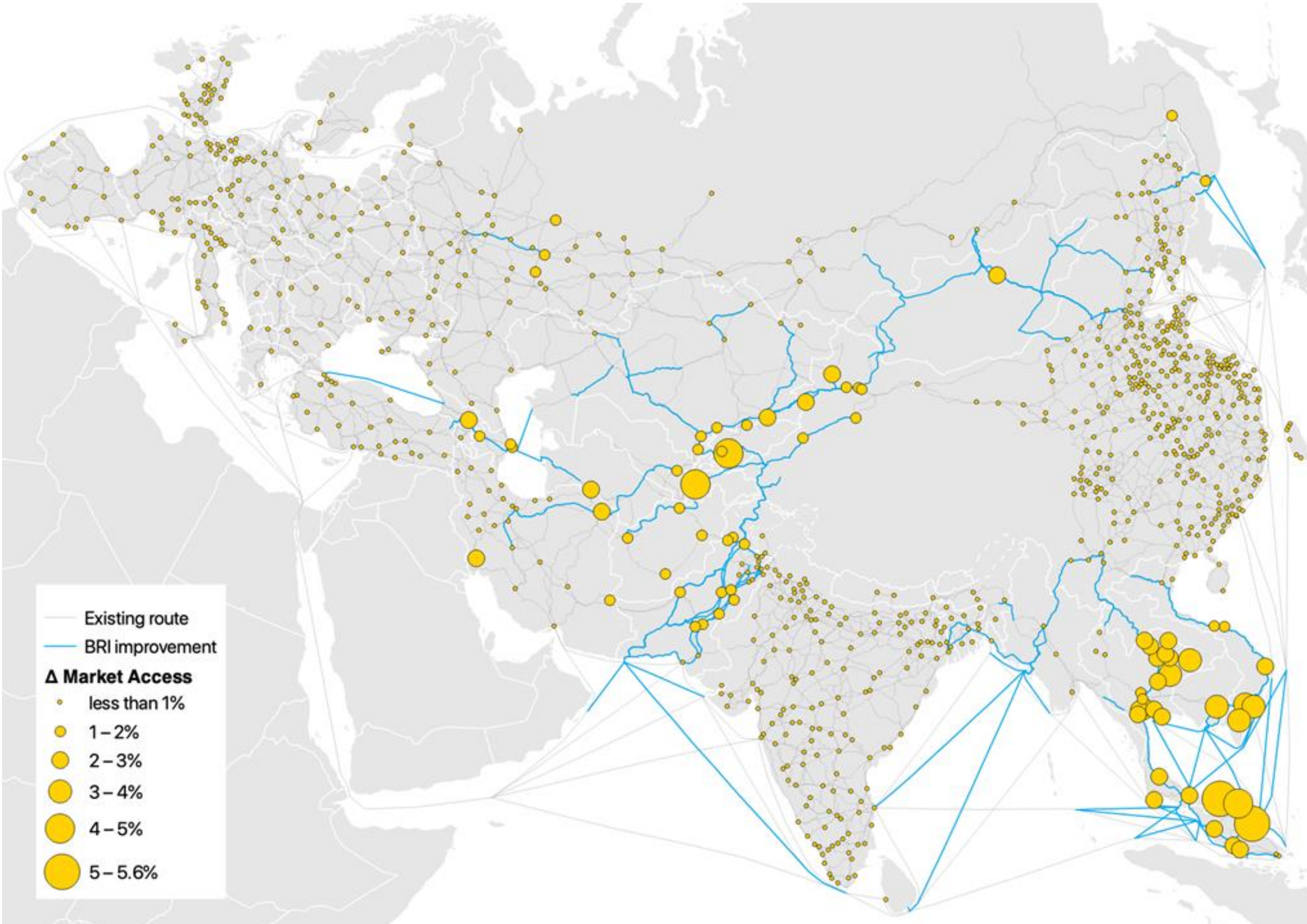
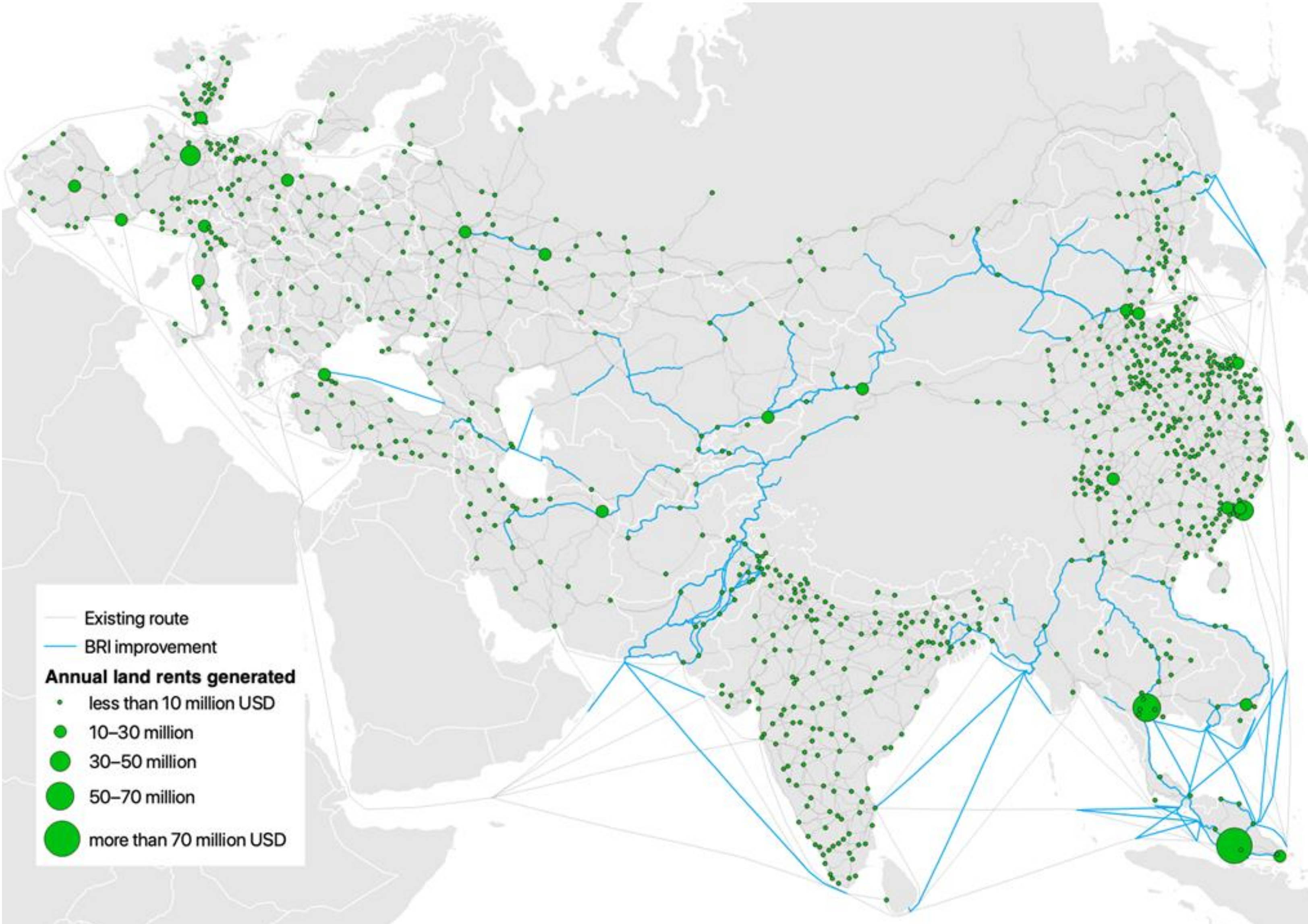


Figure 3: Value created for owners of land when all BRI projects are built in complement



APPENDIX A: DATABASE OF PLANNED BRI ROAD, RAIL AND PORT INVESTMENTS (NOT FOR PUBLICATION)

TABLE A1: SILK ROAD ECONOMIC BELT ("BELT")

CORRIDOR	NO.	PROJECT	IMPROVEMENT SECTION	COUNTRIES	TYPE (SEE TABLE 3)	REF.	STATUS	DETAILS	STATUS DATE	STATUS REF.
CHINA-MONGOLIA-RUSSIA ECONOMIC CORRIDOR (CMREC)	1.	Central Rail Corridor	Ulan-Ude–Ulaanbaatar–Erenhot	Russian Federation, Mongolia	Rail upgrade	(1)	Operational	Already in use. European, Mongolian and Chinese firms are using the corridor.	30-Sep-18	(2)
			Erenhot–Beijing–Tianjin	China	Rail upgrade	(1)				
	2.	Northern Rail Corridor	Kuragino – Kyzyl	Russian Federation	New rail	(1)	Planning	Construction started on section to Ovoot coal mine, to finish in 2019. Section beyond Ovoot is only planned. Final feasibility study approved in April 2018. Delays due to funding shortfalls.	10-Apr-18	(2) (3)
			Kyzyl–Arts Suur–Ovoot	Russian Federation, Mongolia	New rail	(1)				
			Ovoot–Erdenet	Mongolia	New rail	(1)				
			Erdenet–Salkhit	Mongolia	Rail reconstruction	(1)				
	3.	Western Rail Corridor	Arts Suur–Urumqi	Mongolia, China	New rail	(1)	Proposed	Proposed under Mong. national rail policy and joint China-Mong.-Rus. declaration. No concrete steps taken.	25-Nov-2018	(1) (4)
	4.	Eastern Rail Corridor	Choibalsan–Bichigt	Mongolia	New rail	(1)	Proposed	Proposed and still being discussed. China, Russian	23-Jan-2018	(5)
			Bichigt–Chifeng	China	New rail	(1)				

		Chifeng–Jinzhou	China	Rail reconstruction	(1)		Federation and Mongolia ready to operationalize the agreement.		
5.	Nizhneleninskoye Bridge	Leninskoye–Tongjiang	China, Russian Federation	New rail	(6)	Under Construction	China's side of the railway bridge has been completed already. Massive floods delayed work on Russian side. Russian Federation to complete its section in 2018.	13-Nov-2018	(6) (7)
6.	Seaside 1 Corridor (Primorye-1)	Pogranichny crossing	China, Russian Federation	Border cost reduction	(1)	Operational	Completed and now in use. Corridor links Harbin with Russian Federation through Suifenhe, a Chinese land port. Vostochny sea port is in use. Greatly shortens trip from factory to sea port for northwest China. Eases travel and customs regime between China to Vladivostok.	26-Sep-18	(8)
		Poltavka crossing	China, Russian Federation	Border cost reduction	(9)				
		Harbin–Ussuriysk	China, Russian Federation	Rail upgrade	(9)				
		Ussuriysk–China border	Russian Federation	Road reconstruction	(9)				
		Vladivostok–Nakhodka	Russian Federation	New divided road	(9)				
		Vostochny Port	Russian Federation	New seaport	(9)				
7.	Seaside 2 Corridor (Primorye-2)	Choibalsan–Arixan	Mongolia	New rail	(1)	Operational	Launched this year. The first test overload occurred in April 2018 and in September, a new	13-Nov-18	(10)
		Kraskino-Hunchun crossing	China, Russian Federation	Border cost reduction	(9)				

			China border–Zarubino	Russian Federation	New rail	(9)		Hunchun-Zarubino-Ningbo transit line was opened within the Primorye-2. The corridor connects Hunchun, a border city in Jilin Province and the port of Zarubino.		
			China border–Zarubino	Russian Federation	New divided road	(9)				
			Zarubino Port	Russian Federation	New seaport	(9)				
	8.	Highway AH-3	Ulan-Ude–Erenhot	Russian Federation, Mongolia	New road	(1) (11)	Operational	The link was tested for operations in August 2016 and has been in use since. It is Ulaanbaatar's only modern road link to China and Russian Federation.	30-Sep-18	(12)
			Erehnot–Jining	China	Road upgrade	(1)				
	9.	Highway AH-4	Novosibirsk–Khovd–Urumqi	Russian Federation, Mongolia, China	New road	(1)	Operational	Open for use but construction still ongoing. Part of Asian Highway 4 which runs from Novosibirsk to Karachi. Virtually empty from Russian border to Urumqi.	30-Sep-18	(13)
	10.	Southern Coal Railway	Khuut–Tavan Tolgoi–Gushun Suhait	Mongolia	New rail	(4)	Under Construction	Civil works underway in Mongolia, scheduled completion in 2019. Chinese section operational.	12-Feb-18	(14)
			Gushun Suhait–Baotou	China	New rail	(15)				
NEW EURASIAN LAND BRIDGE (NELB)	11.	Khorgos-Aktau Railway	Khorgos–Zhetygen	Kazakhstan	New hicap rail	(16)	Operational	The railway links the world's biggest dry port Khorgos (China) and Aktau port (Kazakhstan). Jezkazgan and Beyneu rail	15-Apr-17	(17)

		Jezkazgan–Saksaulsky	Kazakhstan	New rail	(18)		links completed in 2015. Khorgos opened in 2017. Aktau port is continuously being upgraded but remains operational. This project makes it feasible to ship from Xinjiang to the Caspian sea.		
		Beyneu–Shalkar	Kazakhstan	New rail	(18) (19)				
		Khorgos Dry Port	China, Kazakhstan	Border cost reduction	(16)				
		Aktau Port	Kazakhstan	New seaport	(16)				
12.	Moscow-Kazan HSR	Moscow–Kazan	Russian Federation	New hicap rail	(20)	Proposed	In May 2018, Eurasian Development Bank committed to funding, signing a cooperation agreement with Russian Railways.	30-May-18	(21)
13.	Urumqi-Khorgos rail	Urumqi–Khorgos	China	New hicap rail	(22)	Operational	A new section of railway came into operation between Khorgos and Urumqi.	30-May-18	(23)
14.	Urumqi-Khorgos road	Urumqi–Khorgos	China	New divided road	(24)	Operational	Some construction is ongoing but the road is open for use between China and Kazakhstan.	30-May-18	(23)
15.	Khorgos-Almaty road	Khorgos–Almaty	Kazakhstan	New divided road	(25) (26) (27)	Operational	Currently in use although some related civil works mostly funded by China are still underway.	30-May-18	(23) (28)
16.	Highway P4/A17	Astana–Pavlodar	Kazakhstan	Road upgrade	(26) (27)	Operational	Currently in use although other civil works are still underway.	7-Sep-18	(29) (28)

	17.	Highway M36	Astana–Karaganda	Kazakhstan	Road upgrade	(26) (27)	Operational	Currently in use but Kazakhstan is still embarking on other expansions and upgrades for the road.	7-Sep-18	(30) (28)
	18.	Highway A2	Almaty–Shymkent	Kazakhstan	Road upgrade	(27)	Operational	The upgraded road runs from Almaty to a point past Uzynagash. It continues as two-lane highway to Shymkent.	11-Oct-18	(28)
			Shymkent–Tashkent	Kazakhstan, Uzbekistan	Road upgrade	(26) (27)				
	19.	Highway M32	Shymkent–Tashkent	Kazakhstan, Uzbekistan	Road upgrade	(26) (27)	Operational	Currently in use.	11-Oct-18	(28)
CHINA-CENTRAL ASIA-WEST ASIA ECONOMIC CORRIDOR (CCWAEC)	20.	Tehran-Mashad rail	Tehran–Mashhad	Iran, Islamic Rep.	Rail upgrade	(31)	Under Construction	Electrification project started in 2017 and is projected to be completed in 48 months.	4-May-18	(32)
	21.	Tehran-Isfahan HSR	Tehran–Qom–Isfahan	Iran, Islamic Rep.	New hicap rail	(31)	Under Construction	Construction led by China Railway Engineering Corporation. Expected completion 2021. The Islamic Republic of Iran's first high speed rail connection.	25-Nov-18	(33)
	22.	Kashgar-Tashkent rail	Kashgar–Andijan	China, Kyrgyz Republic, Uzbekistan	New rail	(34)	Proposed	Proposal with potential route but no concrete plans.	19-Feb-18	(34)
			Pap–Tashkent	Uzbekistan	New hicap rail	(35)	Operational	Line opened June 2016.	15-Feb-16	(35)
	23.	Sher Khan-Herat rail	Sher Khan–Kunduz–Herat	Afghanistan	New rail	(36)	Under Construction	Termiz extension operational since 2012.	7-Nov-18	(37) (38)

							Expected completion March 2019.		
24.	Samarkand-Mashhad rail	Samarkand–Ashgabat–Mashhad	Uzbekistan, Turkmen., Iran, Islamic Rep.	Rail upgrade	(39)	Operational	Completed, and now operational.	1-Jun-18	(40)
25.	Kashgar-Dushanbe rail	Kashgar–Dushanbe	China, Kyrgyz Republic, Tajikistan	New rail	(41) (42)	Proposed	Tajikistan and China in talks to build rail.	1-Sept-17	(43)
26.	North-South Alternate Road	Jalalabad–Töö Ashuu	Kyrgyz Republic	Road reconstruction	(44)	Under Construction	In 2013, China Road and Bridge Corporation (CRBC) appointed as contractor, funds linked to a loan from the Export-Import Bank of China.	1-May-18	(45)
27.	Dushanbe-Afghan Rail	Dushanbe–Kolkhozabad	Tajikistan	Rail upgrade	(42)	Proposed	Discussions still underway between China and Tajikistan.	23-Aug-18	(42)
28.	Baku Port	Aktau–Baku Turkmenbashi–Baku	Kazakhstan Turkmenistan	New sea link New sea link	(46) (49)	Operational	Baku, Aktau and Turkmenbashi ports operational. Turkmenbashi opened recently.	5-Jul-18	(47) (48)
29.	Baku-Tbilisi Rail	Baku–Ganja–Tbilisi	Azerbaijan, Georgia	Rail upgrade	(50)	Operational	Launched in October 2017. Though its planning began in 2007, is was postponed several times.	30-Oct-18	(51)
30.	Tbilisi-Kars Rail	Tbilisi – Kars	Georgia, Turkey	New rail	(50)	Operational	Construction officially completed in October 2017 as indicated above.	28-May-18	(52)

	31.	Anaklia port	Anaklia port	Georgia	New port	(53) (54)	Operational	In use but developments are continuing, e.g. reclaiming 5.0 million cubic meters of sand from the sea and placement of the dredged material. To be operational by December 2020	28-Jul-18	(55)
			Anaklia	Georgia	New hicap rail	(53)				
			Anaklia–Istanbul	Georgia, Turkey	New sea link	(53)				
	32.	Ambarli Port	Istanbul	Turkey	New ports and sea links	(53) (56)	Operational	The Port is in use and expansions are still ongoing. Chinese private firms are now making huge investments.	21-Apr-18	(57)
	33.	Piraeus Port	Athens	Greece	Major port expansion	(58)	Operational	New berths were added this year. Piraeus, the 7th largest seaport in Europe was in 2016 sold to a Chinese firm by Greece.	27-Feb-18	(59)
CHINA-PAKISTAN ECONOMIC CORRIDOR (CPEC)	34.	Yarkant Road	Tashkurgan–Yarkant (Shache)	China	New road	(60)	Proposed	No evidence of progress on proposed class-II highway	25-Jun-17	(61)
	35.	Karakoram Highway	Kashgar–Khunjerab	China	Road reconstruction	(62)	Under Construction	Reconstruction of China-Pakistan Highway still underway and is expected to be completed by 2020. Highway follows historic trade route. Khunjerab Pass is the only connection between China and Pakistan. Previous upgrades were done outside scope of	19-Oct-18	(61)
			Raikot–Shinkiari	Pakistan	New road	(60)				
			Shinkiari–Burhan	Pakistan	Road upgrade	(60)				

							BRI after floods washed out Pakistani roads.		
36.	China-Pakistan Rail	Kashgar–Khunjerab–Taxila	China, Pakistan	New rail	(63)	Proposed	Feasibility study planned. Considered a “missing link” in the Asia railway network. Would connect to Chinese rail network at Kashgar (Kashi).	7-Nov-18	(64)
37.	Havelian-Hyderabad capacity expansion (ML-1)	Havelian–Larkana–Hyderabad	Pakistan	Rail upgrade	(60)	Under Construction	Upgrade of ML-1 of Pakistan Railways began in 2018. The project's two phases are expected to be completed by 2022.	21-Mar-18	(65)
38.	Karachi-Peshawar capacity expansion	Karachi–Hyderabad–Lahore–Peshawar	Pakistan	Rail upgrade	(60)	Planning	Under negotiation, but Pakistan recently cut funding by 2 Bn USD. This railway connects all of Pakistan’s major cities and is a transport backbone for the country.	2-Oct-18	(66)
39.	Gwadar rail	Kotla Jam–Quetta–Gwadar	Pakistan	New rail	(60)	Planning	The feasibility study has just been completed awaiting approval from Chinese and Pakistan governments.	2-Apr-18	(67)
40.	Alternative Gwadar rail passage	Gwadar–Karachi	Pakistan	New railroad	(60)	Proposed	As of late 2018, no concrete plans, though still mentioned in discussions.	30-Oct-18	(68) (69)
41.	Besima-Jacobabad rail	Besima–Jacobabad	Pakistan	New railroad	(60)	Planning	In final approval stage. Completion expected 2023.	27-Mar-18	(70)

	42.	M3/M4 Multan Highway	M2/M3 Bridge–Faisalabad–Multan	Pakistan	New road	(60)	Operational	Launched in May 2018 and now in use.	27-May-18	(71)
	43.	Lahore-Abdul Hakeem road upgrade	Lahore–Abdul Hakeem	Pakistan	Road upgrade	(60)	Operational	By October 2018, all upgrades were completed, and the highway is ready for opening to traffic.	9-Nov-18	(72)
	44.	Multan-Sukkur road	Multan–Sukkur	Pakistan	Road upgrade	(60)	Under Construction	The first section of the two-way six-lane road was launched in 2018 and is operational. The rest is under construction and to be completed by 2019.	17-Sep-18	(73)
	45.	Gwadar-Surab road	Gwadar–Panjgur–Surab	Pakistan	New road	(60)	Operational	Launched in 2016 and now operational.	10-Sep-17	(74)
	46.	Surab-DI Khan road	Surab–Quetta–DI Khan	Pakistan	Road reconstructio n	(60)	Operational	Launched in 2017 and now in use.	26-Nov-17	(74) (75)
	47.	M8 Sukkur-Besima road	Sukkur–Shahdadkot–Besima	Pakistan	New road	(60)	Operational	Construction completed in early 2018. Work was finished by the Pakistan Army after Chinese contractors refused to work out of security concerns.	9-Apr-18	(76)
	48.	Shahdadkot-DI Khan road	Shahdadkot–DI Khan	Pakistan	New road	(60)	Planned	Marked as “medium to long-term” on CPEC maps. No evidence of concrete steps.	25-Nov-18	(77)
BANGLADE SH	49.	Kunming-Calcutta HSR	Kunming–Mandalay–	Bangladesh, China, India, Myanmar	New hicap rail	(78)	Proposed	Chinese officials reiterate support for the idea, but no concrete plans.	13-Sep-18	(79)

-CHINA-INDIA-MYANMAR ECONOMIC CORRIDOR (BCIM)			Chittagong–Dhaka–Calcutta							
	50.	Dali-Lashio railway	Dali–Ruili–Lashio	China, Myanmar	New rail	(80)	Under Construction	Under construction since 2011, scheduled for completion in 2021.	26-Sep-18	(81)
	51.	Kalay-Jiribam rail	Kalay–Tamu–Jiribam	Myanmar, India	New rail	(80)	Under Construction	Civil works are underway for the rail which will link India and Myanmar.	18-May-15	(82) (83)
	52.	Dhaka-Bongaon rail	Dhaka–Bongaon	Bangladesh, India	New rail	(80)	Proposed	Still being discussed	5-Sep-18	(84)
	53.	Kyaukpyu port	Kyaukpyu–Ann	Myanmar	New rail	(85)	Planning	On 8 November 2018, Myanmar and China agreed to scale down the project from US$10 Bn to US1.3 Bn, from 10 to 2 berths.	8-Nov-18	(86)
			Kyaukpyu–Mandalay	Myanmar	Road upgrade	(85)				
			Kyaukpyu	Myanmar	New seaport	(87)				
CHINA-INDOCHINA PENINSULA ECONOMIC CORRIDOR (CICPEC)	54.	Kunming-Vientiane rail	Kunming–Vientiane	China, Lao PDR	New rail	(88)	Under Construction	Almost 25% works done, project to be completed by 2021. Kunming-Hekou rail on China side operational, with wider track boosting cargo capacity.	22-Jul-18	(89)
	55.	Bangkok-Vientiane rail	Bangkok–Vientiane	Thailand, Lao PDR	Rail upgrade	(90)	Under Construction	Conventional rail operational since 2009. High Speed Rail upgrade to Nakhon Ratchasima exp. by 2020 with future plans to reach Laos.	11-Feb-18	(91)

56.	East Coast Rail Link (ECRL)	Kuala Lumpur–Kota Bharu	Malaysia	New hicap rail	(92)	Cancelled or postponed	Construction began in August 2017. On 3 July 2018, Malaysia instructed China Communications Construction to suspend all works. On 12 April 2019, works allowed to resume, given a 1/3 cost reduction	13-Sep-18, 4-Nov-18 12-Apr-19	(93)
57.	Gemas-Johor rail upgrade	Gemas–Johor Bahru	Malaysia	Rail upgrade	(94)	Under Construction	Malaysia Transport Minister reports that upgrade is 20% complete, to be finished in 2022	30-Jul-18	(95)
58.	Bangkok-Kuala Lumpur HSR	Bangkok–Pedang Besar–Kuala Lumpur	Thailand, Malaysia	Rail upgrade	(96)	Proposed	Discussions still underway. Operations are targeted to begin by end of 2026.	7-Nov-18	(97)
59.	Kuala Lumpur-Singapore HSR	Kuala Lumpur–Seremban–Singapore	Malaysia, Singapore	New hicap rail	(98)	Cancelled or postponed	Officially suspended on Sep 5, 2018 at Malaysia's request. Singapore officials report that the construction will resume by May 31, 2020.	7-Sep-18	(99)
60.	Vietnam National HSR	Hanoi–Ho Chi Minh City	Vietnam	Rail upgrade	(100)	Proposed	Planning began in 2007, paused in 2010, now being reconsidered.	8-Apr-18	(101)
61	Vietnam-Cambodia rail	Phnom Penh–Ho Chi Minh City	Cambodia, Vietnam	New rail	(102)	Proposed	Still being discussed. Though work on the Bangkok-Phnom Penh rail crossing has commenced.	15-Feb-18, 28-Jun-18	(103) (104)
62.	Burma railway	Nam Tok–Thanbyuzayat	Thailand, Myanmar	New rail	(105)	Planned	Link still being "considered". Railway was built by Japan using forced	22-Jan-18	(106)

								labor in WWII, later destroyed. Difficult terrain and troubled history make construction difficult.		
	63.	Sihanoukville port	Phnom Penh–Sihanoukville	Cambodia	New rail	(107)	Under Construction	Cambodia's only deepwater port. Accompanying special economic zone planned. Expected completion of all projects by 2023.	12-Sep-18	(108)
			Phnom Penh–Sihanoukville	Cambodia	New divided road	(107)				
			Sihanoukville	Cambodia	New seaport	(107)				
	64.	Thai Canal	Satun–Songkhla	Thailand	New sea links	(109)	Proposed	Discussions still underway with Chinese and non-Chinese companies interested. Also known as "Kra Canal". Would provide alternative to Strait of Malacca chokepoint.	6-Apr-18	(110)
ADDENDUM: SELECTED RAIL PROJECTS IN AFRICA	65.	Addis Abeba-Djibouti Railway	Addis Abeba-Djibouti city	Djibouti, Ethiopia	New rail	(111)	Operational	Commercial operations began January 2018. To be operated by Chinese firms until 2023, and after by the Ethio-Djibouti Standard Gauge Rail Transport S.C., a joint venture between Djibouti and Ethiopia.	19-Nov-18	(112) (113)
	66.	Addis Abeba-Nairobi Railway	Addis Abeba-Nairobi	Ethiopia, Kenya	New rail	(114)	Proposed	Kenya-Ethiopia link mentioned among other proposals. No evidence of concrete steps.	25-Nov-18	(115)
	67.	Juba-Mombasa Railway	Juba-Mombasa	Kenya, South Sudan	New rail	(114)	Under Construction	China has agreed to finance and green light has been	16-June-18	(116)

			given by governments. So far only Nairobi-Naivashsa has been built, less than 1/10 of the way to Juba.

TABLE B2: MARITIME SILK ROAD ("ROAD")

PASSAGE	AREA	NO.	PROJECT	COUNTRIES	TYPE (SEE TABLE 3)	REF.	STATUS	DETAIL	STATUS DATE	STATUS REF
CHINA-INDIAN OCEAN-AFRICA-MEDITERRANEAN SEA (CIAM) BLUE ECONOMIC PASSAGE	Indian Ocean (Africa)	68.	Bagamoyo Port	Tanzania	New seaport	(117)	Planned	Port approved in 2013, negotiations still in progress. Possibly shelved by Tanzania gov't in favor of existing Dar es Salaam.	6-Feb-18	(118)
		69.	Dar es Salaam Port	Tanzania	Seaport expansion	(119)	Under Construction	Improvements for Dar es Salaam port commenced.	1-Sep-18	(120)
		70.	Lamu Port	Kenya	New seaport	(121)	Under Construction	In progress. Initiated by Kenya in 2007, completion expected in 2020. Lamu will serve as a terminus for new Chinese-built rail links throughout East Africa.	6-Nov-18	(122)
		71.	Techobanine Port	Mozambique	New seaport	(123)	Proposed	The three countries Mozambique, Botswana and Zimbabwe signed MoU in 2006 but no physical progress. Discussions have been resumed after hiatus.	18-Apr-18	(124)

	72.	Beira Port	Mozambique	Seaport expansion	(125)	Operational	In use, continuous improvements ongoing.	10-Nov-18	(126)
	73.	Gwadar Port	Pakistan	New seaport	(127)	Operational	Expansions to continue until 2025. Port given to China on 40-year lease due to payment difficulties.	2-Apr-18	(66) (128)
Indian Ocean (Asia)	74.	Duqm Port	Oman	New seaport	(129)	Planning	The port is part of Omani's development masterplan initiated in 2011 to make Duqm an important port/city in the Arab World.	4-Jun-18	(130)
	75.	Hambantota Port	Sri Lanka	New seaport	(131)	Operational	In use, improvements still underway, Sri Lanka leased to Chinese state firm to help with construction cost payment.	4-Jun-18	(132)
	76.	Colombo Port City	Sri Lanka	New seaport	(133)	Under Construction	Built on land reclaimed from the Indian Ocean and funded with 1.4 Bn USD Chinese investment. To be completed in 2020. Project aims to create a world class city in Sri Lanka on the model of Dubai.	2-Aug-18	(134)
	77.	Kyaukpyu Port	Myanmar	New seaport	(87)	Planning	Myanmar and China agreed to scale down the project in 2018 from 10 to 1.3 Bn USD. With rail	8-Nov-18	(135)

							link through Myanmar to China, this would present an alternative route to the Strait of Malacca.		
	78.	Melaka Gateway	Malaysia	New seaport	(136)	Under Construction (Stalled)	Port was scheduled for completion in 2019. As of 2018 no construction has been done and regulatory approval has officially lapsed. Future of project is uncertain.	12-Jul-18	(137)
	79.	Kuala Linggi Port	Malaysia	New seaport	(136)	Planned	Minor existing port is in use. Officials have discussed expansion under BRI. Along with Melaka, would provide alternative to Singapore as Strait of Malacca hub.	10-Nov-18	(138)
	80.	Penang Port	Malaysia	New seaport	(136)	Operational	Now in use and cruise ships have started docking.	14-Nov-18	(139)
	81.	Sihanoukville Port	Cambodia	New seaport	(107)	Under Construction	Partly operational; full completion by 2023. Accompanied by special economic zone built on Shenzhen model, touted as "next Macao".	26-Jun-18	(140)
Mediterranean Sea	82.	Suez Economic and Trade Cooperation Zone	Egypt, Arab Rep.	New seaport	(141)	Under Construction	Area provides incentives for Egyptian and Chinese companies to set up factories and R&D with	24-Oct-18	(142)

							focus on tech. Located near Suez Canal.		
	83.	Yuzhny Port	Ukraine	New seaport	(143)	Operational	China Harbor Engineering Company finished work to deepen Yuzhny Port. Located near Odessa, it provides an alternative to Russian-held Sevastopol.	21-Jan-18	(144)
	84.	Piraeus Port	Greece	New seaport	(58)	Operational	In use, new berths were added this year. Piraeus, the 7th largest seaport in Europe was in 2016 sold to a Chinese firm by Greece.	27-Feb-18	(59)
Atlantic Ocean	85.	Cabinda Port	Angola	New seaport	(145)	Under Construction	Work in progress and is being financed by Chinese backed companies.	25-Jan-17	(146)
	86.	N'Diago Port	Mauritania	New seaport	(147)	Under Construction	Work in progress on Mauritania's largest sea port, located near Senegalese border.	13-Dec-17	(148)
	87.	Tema Port	Ghana	New seaport	(149)	Operational	In use but some civil works are still ongoing. There are concerns over government's inability to negotiate a better deal with port developers.	14-Oct-18	(150)
Pacific Ocean	88.	Thai canal	Thailand	New sea links	(109)	Proposed	Thailand still discussing with China to build the new canal. Thailand's new	6-Apr-18	(110)

								king wants to execute the canal project as part of the BRI. Canal would bypass Malacca Strait chokepoint.		
		89.	Kuantan Port	Malaysia	New seaport	(151)	Operational	The upgrading works were completed in 2018, however the port will be affected adversely by the suspension of ECRL project by Malaysia.	4-Nov-18	(95)
CHINA-OCEANIA-SOUTH PACIFIC (COS) BLUE ECONOMIC PASSAGE	Pacific Ocean	—	(none proposed)	—	—	—	—	—	—	—
	Indian Ocean	90.	Darwin Port	Australia	Seaport expansion	(152)	Operational	2015 deal gives Chinese firm Landbridge 99-year lease. Port has now borrowed heavily, raising concerns about debt sustainability.	17-Jun-18	(153)
ICE SILK ROAD (ISR)	Arctic Ocean	91.	Northern Sea Route	Russian Federation	New sea link	(136)	Planning	Potential alternative to Suez Canal between Asia to Europe, shorter distance and more secure. Russian Federation and China are intensifying feasibility studies of this route.	4-Nov-18	(154)
		92.	New Dvina Port	Russian Federation	New seaport	(136)	Planning	This new mega port valued at 2.3 Bn USD would be Russian Federation's central hub for trade with Europe, the	19-Jun-18	(155)

						Asia-Pacific region and North America.		
93.	Kirkenes Port	Norway	New seaport	(156)	Proposed	Railway would link this port to Baltic via Finland, opening up to Europe. Would compete with New Dvina Port.	10-Oct-18	(157)

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APPENDIX B: ROBUSTNESS OF PROJECT RANKINGS (NOT FOR PUBLICATION)

Table B1: Spearman (rank) correlation of changes in (log) market access under different assumptions, when all BRI projects are built in complement

	Baseline	Labor share β =0.8	θ =8.1, for agri-culture	No cost to switch between road and rail	Labor share β =0	Add retail distribution costs	Halfway reduction in trade costs	θ =15.7, for mining	No terminal handling charges	Using simple average tariff	Using pop. instead of GDP for market size	Oxford Economics GDP	No tariffs or border costs	ESCAP-WB tariffs and border costs	Add external markets (Rest of World)
Baseline	1	1	0.99	1	0.98	0.98	0.97	0.97	0.96	0.94	0.91	0.91	0.85	0.76	0.71
Labor share β =0.8	1	1	1	0.99	0.98	0.98	0.98	0.97	0.96	0.95	0.92	0.91	0.85	0.76	0.71
θ =8.11, for agriculture	0.99	1	1	0.99	0.98	0.98	0.98	0.98	0.96	0.94	0.92	0.92	0.85	0.75	0.72
No cost to switch between road and rail	1	0.99	0.99	1	0.98	0.98	0.97	0.97	0.96	0.94	0.92	0.91	0.85	0.76	0.72
Labor share β =0	0.98	0.98	0.98	0.98	1	0.97	0.96	0.97	0.94	0.93	0.93	0.93	0.87	0.77	0.71
Add retail distribution costs	0.98	0.98	0.98	0.98	0.97	1	0.96	0.96	0.95	0.96	0.9	0.89	0.86	0.77	0.71
Halfway reduction in trade costs	0.97	0.98	0.98	0.97	0.96	0.96	1	0.96	0.95	0.92	0.89	0.89	0.83	0.72	0.69
θ =15.72, for mining	0.97	0.97	0.98	0.97	0.97	0.96	0.96	1	0.93	0.92	0.92	0.92	0.83	0.74	0.72
No terminal handling charges	0.96	0.96	0.96	0.96	0.94	0.95	0.95	0.93	1	0.92	0.86	0.86	0.81	0.73	0.7
Using simple average tariff	0.94	0.95	0.94	0.94	0.93	0.96	0.92	0.92	0.92	1	0.88	0.86	0.83	0.78	0.7
Using population instead of GDP for market size	0.91	0.92	0.92	0.92	0.93	0.9	0.89	0.92	0.86	0.88	1	0.97	0.85	0.81	0.77
Oxford Economics GDP	0.91	0.91	0.92	0.91	0.93	0.89	0.89	0.92	0.86	0.86	0.97	1	0.85	0.81	0.8
No tariffs or border costs	0.85	0.85	0.85	0.85	0.87	0.86	0.83	0.83	0.81	0.83	0.85	0.85	1	0.83	0.7

ESCAP-WB tariffs and border costs	0.76	0.76	0.75	0.76	0.77	0.77	0.72	0.74	0.73	0.78	0.81	0.81	0.83	1	0.64
Add external markets (Rest of World)	0.71	0.71	0.72	0.72	0.71	0.71	0.69	0.72	0.7	0.7	0.77	0.8	0.7	0.64	1

APPENDIX C: COUNTERFACTUAL OUTPUT ACCOUNTING FOR FACTOR MOBILITY (NOT FOR PUBLICATION)

Step 1: Estimate Baseline Productivity and Land Quantity

Begin with equation (5) from Donaldson and Hornbeck (2016), originally a result of Eaton and Kortum (2002), which gives the value of total exports from o to d,

$$X_{od} = \kappa_1 A_o (q_o^{\alpha} w_o^{\beta})^{-\theta} \tau_{od}^{-\theta} CMA_d^{-1} Y_d.$$

Sum this equation over all locations *d*, and apply the goods market clearing condition to yield each location's total output

$$Y_o = \sum_d X_{od} = \kappa_1 A_o (q_o^{\alpha} w_o^{\beta})^{-\theta} \sum_d \tau_{od}^{-\theta} CMA_d^{-1} Y_d = \kappa_1 A_o (q_o^{\alpha} w_o^{\beta})^{-\theta} FMA_o.$$

Combining equations (3) and (4) from Donaldson and Hornbeck (2016) yields the spatial equilibrium condition in terms of consumer market access, $w_o = \bar{U} P_o = \bar{U} CMA_o^{-1/\theta}$. Further, due to the Cobb Douglas technology, $L_o q_o = \alpha Y_o$. Substitute these two identities into the equation above and take logs to yield

$$\ln(Y_o) = \ln(\kappa_1) + \ln(A_o) - \theta\alpha \ln\left(\frac{\alpha Y_o}{L_o}\right) + \beta \ln(\bar{U} CMA_o) + \ln(FMA_o).$$

Rearranging terms yields

$$\boldsymbol{(1+\theta\alpha)\ln(Y_o) = \kappa_2 + \ln\left(A_o L_o^{\alpha\theta}\right) + \beta \ln(CMA_o) + \ln(FMA_o)}, \qquad (5)$$

where $\kappa_2 = \ln\left(\frac{\kappa_1}{\alpha^{\alpha\theta}\, \bar{U}^{\gamma\theta}}\right)$. The normalization of $\bar{U}$ such that $\kappa_2 = 0$ yields an expression for that allows us to infer productivity (normalized by the quantity of land) from only baseline output, consumer market access and firm market access. We call this

$$\ln(\hat{T}_o) \equiv \ln\left(A_o L_o^{\alpha\theta}\right) = (1+\theta\alpha)\ln(Y_o) - \beta \ln(CMA_o) - \ln(FMA_o).$$

Step 2: Calculate Counterfactual Output.

Equation (5) defines counterfactual output and utility as a function of estimated baseline productivity and the new values of consumer and firm market access:

$$\ln(Y'_o) - \kappa'_3 = \frac{1}{(1+\theta\alpha)} \left[\ln(\hat{T}_o) + \beta \ln(CMA'_o) + \ln(FMA'_o) \right] \qquad (6)$$

where $\kappa'_3 = \frac{1}{(1+\theta\alpha)} \ln\left(\frac{\kappa_1}{\alpha^{\alpha\theta}\,(\bar{U}')^{\gamma\theta}}\right)$ and the term $\bar{U}'$ is utility after the road is constructed. This equation highlights that the new values of market access can result in multiple values of counterfactual output, depending on whether total utility changes as a result of the investment. As described in Donaldson and Hornbeck, the change in $\bar{U}'$ depends on whether the network is open to foreign factors; that is, whether additional population and capital from countries outside the BRI can move to BRI cities.

If the BRI countries are small enough, total utility remains fixed ($\bar{U}' = \bar{U}$) and equation (6) becomes

$$\ln(Y'_o) = \frac{1}{(1+\theta\alpha)} \left[\ln(\hat{T}_o) + \beta \ln(CMA'_o) + \ln(FMA'_o) \right] \qquad (7)$$

Theorem 1 of Allen and Arkolakis (2014) states that Y_o' is a unique fixed point, which may be found through an iterative algorithm. To find it, begin by plugging into the right hand side of (7) values of CMA'_o and FMA'_o calculated using τ'_o, the new set of transportation costs, and Y_o, the original values of output in each location. This yields a new value of Y_o'. Next, recalculate CMA'_o and FMA'_o using this new value of output in each location, and plug them back into (7) to yield a next value of Y_o'. Eventually this will converge to the unique fixed point.