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Common Transport Infrastructure: A Quantitative Model and Estimates from the Belt and Road Initiative[1]

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Abstract

This paper presents a structural general equilibrium model to analyze the effects on trade, welfare, and gross domestic product of common transport infrastructure. The model builds on Caliendo and Parro (2015) to allow for changes in trade costs due to improvements in transportation infrastructure, financed through domestic taxation, connecting multiple countries. The model highlights the trade impact of infrastructure investments through cross-border input-output linkages. This framework is then used to quantify the impact of the Belt and Road Initiative. Using new estimates on the effects on trade costs of transport infrastructure related to the initiative, the model shows that gross domestic product will increase by up to 3.4 percent for participating countries and by up to 2.9 percent for the world. Because trade gains are not commensurate with projected investments, some countries may experience a negative welfare effect due to the high cost of the infrastructure.

Keywords: Transportation infrastructure, trade, structural general equilibrium, belt and road
JEL Codes: F10, F11, F14

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1. Introduction

Through trade agreements, countries have for a long time cooperated to reduce trade costs resulting from tariffs and other policy barriers to international trade. Cooperation on building common transport infrastructure is a more recent and less frequent phenomenon, but potentially as important to reduce international trade costs. For example, since the 1990s the European Union set up a common infrastructure policy to support the functioning of the internal market. The Trans-European Transport Network (TEN-T), in particular, is focused on the implementation and development of a Europe-wide network of transport infrastructure. China's Belt and Road Initiative (BRI) proposes infrastructure investments along the Silk Road Economic Belt -the "Belt"- and the New Maritime Silk Road -the "Road"- which will connect Asia, Europe and East Africa. Large-scale common transport infrastructure projects, or corridors as they are sometimes referred to, are becoming more prominent in Central Asia (e.g. Central Asia Regional Economic Cooperation (CAREC) program), Africa (e.g. Maputo Corridor, Abidjan-Lagos Corridor) and other parts of the developing world.[2]

Common transport infrastructure can improve welfare, but it also creates challenges for countries participating in the projects. For any country, building a railway or a road has some value, but it also has value to the countries around it since improvements in one part of the transport network reduce shipping times for all countries in the network. If each country alone decided how to invest in infrastructure, there are spillovers that would not be taken into account. The value of these investments also depends on what countries do, such as the standards that are used to build these infrastructures or the procedures that countries require to clear goods at the border. This is even more true when transport infrastructure crosses one or more borders pointing to the value of international cooperation in this area. But common transport infrastructure also creates challenges, as it has large implications for public finances and may have asymmetric effects on the trade and gross domestic product (GDP) of individual countries. This raises the possibility that the countries that will build - and bear the cost of – large sections of the project may not be the ones that will gain from it the most.

This paper presents a framework to analyze the trade, GDP and welfare effects of common transport infrastructure. This is an indispensable first step to assess the value of large-scale projects for the countries that will participate, as a group and individually, and for non-participating countries. Our analysis is based on the framework developed by Caliendo and Parro (2015), which we extend to study the impact of infrastructure investment.[3] The underlying framework is a Ricardian model of sectoral linkages, trade in intermediate goods and sectoral heterogeneity in production. Specifically, we enrich the Caliendo and Parro (2015) framework in two ways. First,

[2] See for instance ADB et al. (2018).
[3] The Caliendo and Parro (2015) model builds on the seminal contribution from Eaton and Kortum (2002).

we allow trade costs to depend on shipping times, which will be directly affected by the investment in transport projects, in addition to tariffs and policy barriers. The importance of time as a trade barrier has been established in a number of papers including Hummels (2001), Hummels, Minor, Reisman and Endean (2007), Djankov, Freund and Pham (2010), and Hummels and Schaur (2013). For instance, Hummels and Schaur (2013) estimate that a one-day delay in shipping time is equivalent to an ad-valorem tariff of around 5 percent.[4] Second, we account in the model for the implications of infrastructure investment for the government budget and domestic taxation. Hence, relative to quantitative models for trade policy analysis, the study of common transport infrastructure requires information on the changes in bilateral trade costs associated to the changes in shipping times due to the new infrastructure and estimates of the cost of building the transportation infrastructure for each country.

Despite its complexity, this framework presents the advantage that regardless of the number of sectors and how complicated the interactions between sectors are, the model can be reduced to a system of one equation per country. Moreover, counterfactuals can be performed without prior knowledge of fundamentals such as sector-level total factor productivity or employment, rendering this framework ideal for policy analysis. The model is therefore well suited to analyze the shock due to common transport infrastructure. It shows that when a sector experiences a decrease in the price of its imported inputs as shipping times/trade costs fall, it passes on the associated reduction in production costs to downstream industries, propagating the benefits across the world. These input-output linkages lead to potentially complex reallocation of comparative advantage, production and trade, thus increasing welfare. At the same time, the need to finance transport infrastructure leads to higher taxes that reduce real consumption. The net welfare effect for each country results from the combination of the trade gains and the share of the costs of the common infrastructure.

We then use this framework to estimate the trade, GDP and welfare effects of the transport infrastructure related to the Belt and Road Initiative for 55 participating countries and a total of 107 countries/regions in the world (Figure 1). We use a combination of geographical data and network algorithms to compute the reduction in shipping time and trade costs between all country pairs in the world. [5] The computations are based on the Shortest Path Algorithm on both the current

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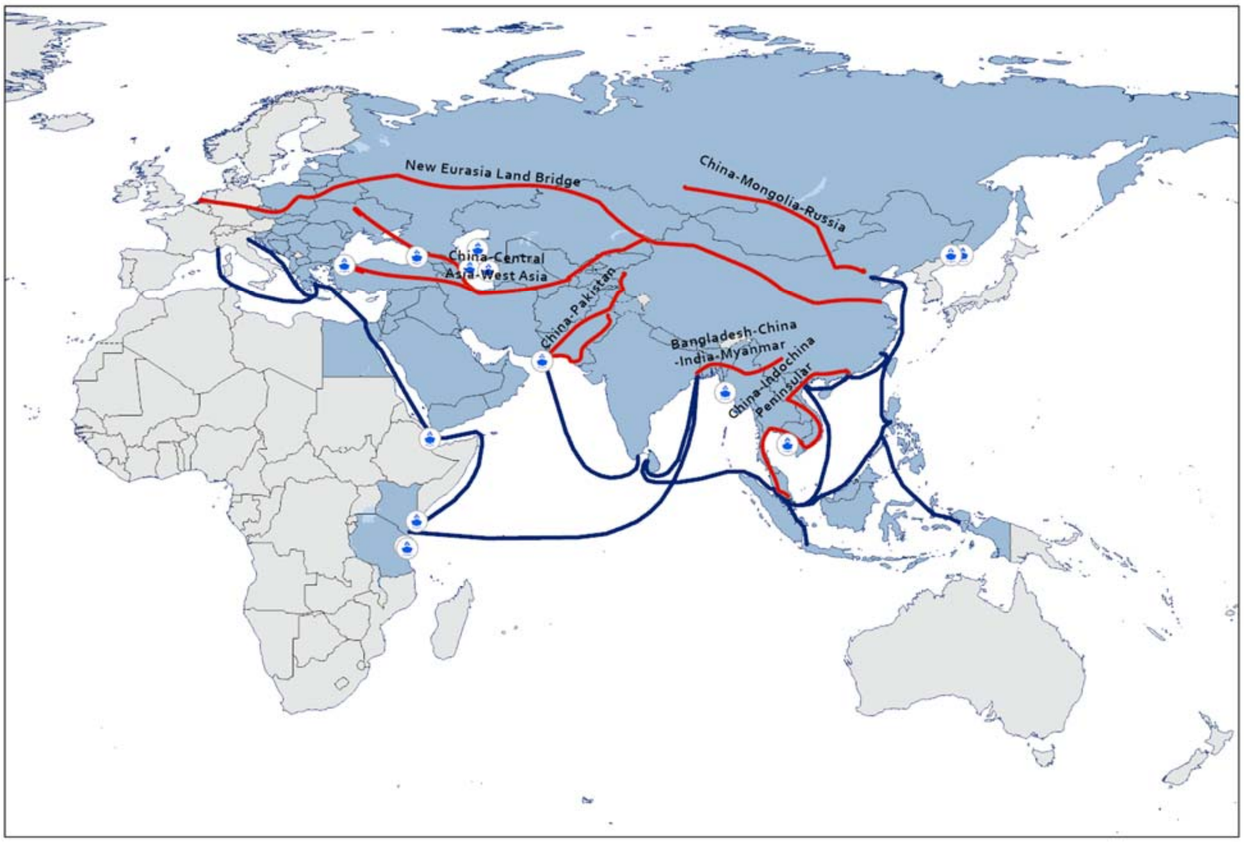
[4] Hummels and Schaur (2013) estimate the "value of time" both at the sectoral level as well as for all goods together. When including all goods and controlling for product fixed effects, they find that a one-day delay in shipping time is equivalent to an ad-valorem tariff of 0.6 to 2.3 percent. Separating each HS2 in different regressions, the average across all products is around 5 percent. de Soyres et al (2019) use the rich heterogeneity of Hummels and Schaur's (2013) estimates at the HS2 level in order to account for each sector's specificity in their sensitivity to time barriers.

[5] The infrastructure projects considered in this study are the ones currently being constructed, planned or proposed as part of the BRI (see de Soyres et al. (2019) for the full list). We do not consider the question of whether this set of projects is optimal for participating countries as a group or for individual countries.

network and an improved network enriched with infrastructure projects covered under the BRI. As a result, the paper estimates the impact of the BRI on the reduction in shipping time between all pairs of cities, which are subsequently aggregated at the country-pair level. Using Hummels and Schaur (2013) sectoral estimates of "value of time", those shipping time reductions are then transformed into reductions in ad-valorem trade costs. We also construct our estimates of the infrastructure costs associated with the BRI for each country.[6]

Figure 1: The Belt and the Road



[6] When constructing our estimates, it is important to ensure that the list of projects we are taking into account is exactly the same as the projects used in the estimation of trade cost reduction in de Soyres et al (2019). As a result, one cannot simply use aggregate cost estimates from official sources (when available) since those numbers do not include only transport projects. In this paper, we re-estimate the costs using a bottom-up approach as described in Section 3. An important caveat is that we assume projects are implemented fully and efficiently -e.g. costs related to corruption or other forms of unproductive behavior are not considered in the analysis.

Our results show that BRI transport infrastructure projects increase GDP for BRI economies by up to 3.35 percent and welfare, which accounts for the cost of infrastructure, by up to 2.81 percent.[7] These effects are equivalent to the impact of a coordinated tariff reduction by one-third for all BRI economies. We also show that the gains from trade are not necessarily commensurate to the investments paid by each country and are highly asymmetric. Indeed, we find that three countries (Azerbaijan, Mongolia and Tajikistan) experience welfare losses as infrastructure costs overweigh gains. In order to equalize all welfare gains among BRI members, it would be necessary that some countries with large gains in the baseline allocation compensate countries with losses. Finally, we show that the welfare effects of BRI transport projects would increase by a factor of 4 if participating countries were to reduce by half the delays at the border and tariffs. All countries gain when the infrastructure projects are coupled with policy reforms.

The model also shows that BRI-related transport projects could increase GDP for non-BRI countries by up to 2.61 percent and for the world as a whole by up to 2.87 percent. These numbers are larger than typical findings for regional trade agreements such as NAFTA using a similar methodology. Contrary to regional trade agreements, which decrease tariffs within a narrowly defined set of countries, the BRI is expected to decrease trade costs between a very large number of countries, including many economies that are not part of the initiative but whose trade flows will benefit from the improved transport infrastructure network when accessing (or transiting through) BRI countries.

Our work contributes to three strands of the literature in international and development economics. First, as already mentioned, we extend a by now standard general equilibrium framework to analyze the effects of trade policy cooperation (Caliendo and Parro, 2015) to address the question of the impact of common transport infrastructure. Second, our work relates to the recent literature on the economic effects of transport infrastructure (Donaldson and Hornbeck, 2016; Allen and Arkolakis, 2017; Fajgelbaum and Schaal, 2017; Donaldson, 2018; Santamaria, 2018). Differently from these papers, our focus is on the quantification of the international trade effects of common infrastructure projects. The third recent strand of the literature focuses on the economic effects of the Belt and Road Initiative. Recent papers have looked at various aspects, including trade effects using a gravity model (Baniya et al., 2018) and Computable General

[7] Those results are quantitatively higher than the Computable General Equilibrium (CGE) analysis in Maliszewska and van der Mensbrugghe (2019). Differently from the CGE analysis, our structural model assumes stronger complementarities between foreign and domestic inputs, with a Cobb-Douglas aggregation in the production function, as in Caliendo and Parro (2015). Moreover, Maliszewska and van der Mensbrugghe (2019) have a more detailed structure of the economy, which comes at the expense of higher level of aggregation of countries into large regions. The finer disaggregation in our model allows to capture the impact of lower trade costs associated to BRI transportation projects on trade flows for a larger number of countries. These intra-regional effects appear to be quantitatively relevant as most country-pairs in the world will experience a decrease in trade cost due to the BRI transportation projects. This effect is magnified when there are important complementarities between foreign and domestic inputs in production.

Equilibrium analysis (Zhai, 2018; Maliszewska and van der Mensbrugghe, 2019), spatial effects (Bird et al., 2019; Lall and Lebrand, 2019), and debt sustainability (Bandiera and Tsiropoulos, 2019).

The paper is structured as follows. Section 2 presents a quantitative model to study the effects of common transport infrastructure. The following section estimates the effects of transport infrastructure projects related to the Belt and Road Initiative on 53 participating countries and a total of 107 countries in the world. Concluding remarks follow.

2. A model of infrastructure investment and international trade

In order to quantify the consequences of common transport infrastructure, we use a quantitative model of international trade based on Caliendo and Parro (2015). We extend this framework along two dimensions: we allow for changes in trade costs due to the reduction in shipping times associated to transport infrastructure and we adapt the model to account for budgetary implications of the infrastructure projects.

a. Households

Consider a world economy with N countries indexed by i and n, and J sectors indexed by j and k. Following Caliendo et al. (2018), households supply labor in return for a wage w_n and are the owner of a fixed factor (land/structures).[8] In particular, we assume that each country has an endowment of H_n units of land and structures which are rented to firms at a rental rate r_n. We assume the presence of a global portfolio and consider the case in which all rents from the fixed factor are sent to the global portfolio and in return each country receives $\iota_n \chi$, where $\chi = \sum_{n=1}^{N} r_i H_i$ is the global income from the portfolio and ι_n the share of the global portfolio income that country n obtains.

In country n, a representative agent choses consumption in order to maximize its indirect utility:

$$v_n = max \prod_{j=1}^{J} \left(C_n^j\right)^{\alpha_n^j}$$

where c_n^j are goods from sector j consumed in country i, and α_n^j is the share of sector j in total final consumption in country n, with $\sum_j \alpha_n^j = 1$.

[8] As discussed in Caliendo et al. (2018), the presence of a fixed factor in the model allows to endogenize trade imbalances in a static framework.

In order to account for the cost of building transport infrastructure, we assume that households are subject to a lump-sum tax, τ_n^L. On top of labor income and the rent from the fixed factor, households also receive the proceeds from import tariffs t_{ni}^j. The household budget constraint is then given by:

$$\sum_{j=1}^{J} p_n^j C_n^j = w_n L_n - \tau_n^L + \iota_n \chi + T_n$$

where p_n^j and c_n^j are the price and consumption level of sectoral goods j from country n and T_n is total revenues from import tariffs. For later purposes, we define household' revenue as $I_n \equiv w_n L_n - \tau_n^L + \iota_n \chi + T_n$. Denoting by M_{ni}^j total country n's imports from country i in sector j, the associated tariff revenues is simply defined by:

$$T_n \equiv \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{t_{ni}^j}{(1 + t_{ni}^j)} M_{ni}^j \tag{1}$$

Denoting by $P_n = \prod_{j=1}^{J} \left(P_n^j / \alpha_n^j\right)^{\alpha_n^j}$ the price index in country n, the value of consumption is then given by $P_n C_n = I_n$ and welfare in country n is given by:

$$U_n = \frac{I_n}{P_n} = \frac{w_n L_n + \iota_n \chi + T_n}{P_n} - \frac{\tau_n^L}{P_n}. \tag{2}$$

In the above equation, it is apparent that the welfare effect of investing in transport infrastructure depends on the difference between the welfare gains that can be achieved through higher real consumption (the first term) and the real cost of investment (the second term). Note that all variables in equation (2) represent annual values. We will come back to this conceptual issue in Section 3.

b. Government

In Caliendo and Parro (2015), the government is passive and simply collects tariff revenues that are rebated lump sum to households. In addition to this function, the role of the government in this economy is to pay for infrastructure projects. Specifically, we assume infrastructure investments are financed through household lump sum taxation, where the value of the tax is derived from our estimation of infrastructure costs described in section 3.a. In any country, the household's lump sum tax τ_n^L is set so that $\tau_n^L = D_n^{annual}$ where D_n^{annual} is the annualized investment linked to BRI infrastructures in country n considered in our analysis. We come back to this object in detail in section 3. a.[9]

c. Production and trade

Representative firms in each country n and sector j produce a continuum of intermediate goods with idiosyncratic productivities z_n^j, using a Cobb-Douglas aggregate of domestic labor and fixed factors as well as intermediate inputs from all other sectors. The production function of a variety with idiosyncratic productivity z_n^j is given by:

$$q_n^j(z_n^j) = z_n^j \left[A_n^j h_n^j(z_n^j)^{\beta_n} \ell_n^j(z_n^j)^{(1-\beta_n)} \right]^{\gamma_n^j} \prod_{k=1}^{J} M_n^{jk}(z_n^j)^{\gamma_n^{jk}}. \tag{3}$$

where $\ell_n^j(z_n^j)$ and $h_n^j(z_n^j)$ are respectively the quantity of domestic labor and fixed factor (land/structures) used in the production of variety z_n^j while $M_n^{jk}(z_n^j)$ denotes the composite input from sector k. With Cobb-Douglas production and abstracting from capital input, one can simply interpret the coefficient γ_n^j as being the share of value added in gross output in sector j and country k, while the set of coefficients γ_n^{jk} for all k are the sectoral shares in production. We assume that $\gamma_n^j + \sum_{k=1}^{J} \gamma_n^{jk} = 1$, ensuring constant returns to scale in production, which, together with a perfectly competitive behavior leads to the absence of profit in the model.

Following Eaton and Kortum (2002), we use a probabilistic representation of technology and assume that production efficiency in sector j and country n is the realization of a random variable Z_n^j drawn independently for each pair (n, j) from a Fréchet distribution with a cumulative distribution function $F(.)$ defined as: $F_n^j(z) = e^{-K_n^j z^{-\theta^j}}$. Parameter K_n^j governs the location of the distribution with a bigger K_n^j implying that a high efficiency draw for a variety in sector j and country n is more likely and is related to the notion of absolute advantage. The parameter θ^j, which we treat as common across countries for each sector, is an inverse measure of the amount of variation within the distribution and is related to the notion of comparative advantage.[10] Productivity of all firms is also determined by a deterministic productivity level A_n^j which can be thought of as the fundamental TFP.

[9] Note that both the income stemming from the tariff rebate and the cost due to infrastructure investments impact the household budget constraint through lump sum transfers, so that the net effect on household disposable income can be either positive or negative depending the relative size of each element.

[10] We assume that $1 + \theta_n^j > \sigma^j$, which is a necessary condition for the prices to be well defined. See Eaton and Kortum (2002) for more on this.

Given the production function (3), standard cost minimization yields the following expression for the cost of the input bundle needed to produce varieties in (n, j):

$$x_n^j = B_n^j \left[r_n^{\beta_n} w_n^{(1-\beta_n)}\right]^{\gamma_n^j} \prod_{k=1}^{J} (P_n^k)^{\gamma_n^{jk}} \tag{4}$$

where B_n^j is a constant.[11] The unit cost of a good of a variety with draw z_n^j in (n, j) is then given by:

$$c(n, j, z_n^j) = \frac{x_n^j}{z_n^j} \left(A_i^j\right)^{-\gamma_n^j} \tag{5}$$

Firms are perfectly competitive and production exhibits constant returns to scale, implying that prices are equal to marginal cost. As is standard in models with input-output linkages, the price of any given sector depends on the price of its suppliers as well as the suppliers of its suppliers, so that all prices in the economy must be jointly solved and are the solution of:

$$p_n^j(z^j) = min_i \left\{ \frac{x_i^j \kappa_{ni}^j}{z_i^j} \left(A_i^j\right)_i^{-\gamma_n^j} \right\} \quad \forall\, j, n \tag{6}$$

where κ_{ni}^j are ad-valorem trade costs which are defined as follows: For each country-pair and sector, κ_{ni}^j is assumed to take the form

$$\kappa_{ni}^j \equiv \left((1 + t_{ni}^j) + transport_{ni}^j + s_{ni}^j(\{G_k\}_{k=1}^N) \right) * \tilde{d}_{ni}^{\,j} \tag{7}$$

where t_{ni}^j and $transport_{ni}^j$ are the sector-specific ad-valorem tariff and transport costs respectively for imports from country n into country i. s_{ni}^j measures the specific barrier due to shipping time from country n to country i as discussed for example in Hummels and Schaur (2013). Common transport infrastructure investment between any two countries affects this component of the trade cost. As is apparent in the notation, this latter component is affected by infrastructure spending not only in countries n and i but also potentially in all countries in the world. Indeed, in our network analysis in Section 3, we actually see that the shipping time between two countries can decrease even if neither of those countries improve their own transport network. This typically happens when any middle country or group of countries, along the way from i to n,

[11] $B_n^j = \left[\gamma_n^j\right]^{-\gamma_n^j} \prod_{k=1}^{J} \left[\gamma_n^{jk}\right]^{-\gamma_n^{jk}}$.

invests in its own transport infrastructure. Intuitively, in a network an improvement in any link can potentially yield benefit for many nodes, not only the nodes directly connected to the improved link. Finally, $\tilde{d}_{ni}^{j}$ are other trade barriers that are non-tariffs, non-transport and non-shipment time related.

Prices in a given sector and country is the aggregate of the prices of all varieties using a CES function. Given the assumptions of Fréchet distribution, the resulting price index in sector j and region n can be written in closed form as:

$$P_n^j = \xi_n^j \left(\sum_{i=1}^{N} \left(x_i^j \kappa_{ni}^j \right)^{-\theta^j} \left(A_i^j \right)^{\theta^j \gamma_i^j} \right)^{-\frac{1}{\theta^j}} \tag{8}$$

where ξ_n^j is a constant and the cost of the input bundle x_i^j is defined in (4).

Finally, using the properties of the Fréchet distribution we can derive expenditure shares as a function of technologies, prices and trade costs as:

$$\pi_{ni}^j = \frac{X_{ni}^j}{X_n^j} = \frac{\left(x_i^j \kappa_{ni}^j \right)^{-\theta^j} \left(A_i^j \right)_i^{\theta^j \gamma_i^j}}{\sum_{i'=1}^{N} \left(x_{i'}^j \kappa_{ni'}^j \right)^{-\theta^j} \left(A_{i'}^j \right)^{\theta^j \gamma_i^j}} \tag{9}$$

where X_n^j is total expenditure in country n and sector j. Note that π_{ni}^j decreases with country i's input costs, x_i^j, and trade costs, κ_{ni}^j.

d. Equilibrium conditions

An equilibrium of this economy is defined as a vector of input prices (wages and rental rate of structure) as well as sector-country prices that satisfy equation (8) and such that all markets clear.

In the goods market, the clearing condition simply equates total production for each sector-country with total absorption, including intermediate and final good flows:

$$X_n^j = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{k=1}^{J} \frac{\pi_{in}^{k}}{1 + t_{in}^k} X_i^k + \alpha_n^j I_n \tag{10}$$

with trade shares defined by (9). In the presence of cross-country transfers governed by the global portfolio, trade balance is given by equating the sum of exports and the portfolio payment to total imports:

$$\sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{ni}^{j}}{1+t_{ni}^{j}}X_{n}^{j}+\Upsilon_{n}=\sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{in}^{j}}{1+t_{in}^{j}}X_{i}^{j} \tag{11}$$

where $\Upsilon_n = r_n H_n - \iota_n \chi$ is the net contribution to the global portfolio. As in Caliendo et al (2018), we assumed that portfolio shares are fixed and will be calibrated to match the observed level of total trade imbalance for each country. When performing counterfactuals, this means that changes in total trade imbalances will be solely governed by changes in the size of the portfolio.

Following Dekle et al. (2008) and Caliendo and Parro (2015), we write equilibrium conditions in relative changes after a policy shock. Differently from the literature, which focuses on changes in trade costs due to trade policy shocks, in this paper we keep tariffs constant and instead consider a change in shipping times due to improvements in transportation infrastructure. Financed through domestic taxation. We now express an equilibrium under trade costs $\kappa_{ni}^{j'}$ relative to a base year equilibrium with trade costs κ_{ni}^{j}, for all n, i and j.

Let us define, for any variable x, the ex-post value as being x' and the relative change as $\hat{x} = x'/x$. Using the equations above, we provide all equilibrium conditions in relative changes in appendix. For simplicity, we focus here just on the equations that are helpful to gain intuition on the economic mechanism at play:

Cost of inputs

$$\hat{x}_{n}^{j}=\left[\hat{r}_{n}^{\beta_{n}}\hat{w}_{n}^{(1-\beta_{n})}\right]^{\gamma_{n}^{j}}\prod_{k=1}^{J}\left(\hat{P}_{n}^{k}\right)^{\gamma_{n}^{jk}} \tag{12}$$

Prices

$$\hat{P}_{n}^{j}=\left(\sum_{i=1}^{N}\pi_{ni}^{j}\left(\hat{x}_{i}^{j}\hat{\kappa}_{ni}^{j}\right)^{-\theta^{j}}\left(\hat{A}_{i}^{j}\right)^{\theta^{j}\gamma_{i}^{j}}\right)^{-1/\theta^{j}} \tag{13}$$

Trade shares

$$\hat{\pi}_{ni}^{j} = \left(\frac{\hat{x}_{i}^{j}\hat{\kappa}_{ni}^{j}}{\hat{P}_{n}^{j}}\right)^{-\theta^{j}} \left(\hat{A}_{i}^{j}\right)^{\theta^{j}\gamma_{i}^{j}} \tag{14}$$

e. Effects of infrastructure investment

Before moving to the calibration and the quantitative assessment of the Belt and Road Initiative, we pause to make some comments on the prediction that can be derived using this structural model. The shock considered in this paper is a proportional change in trade cost $\hat{\kappa}_{ni}^{j}$ following the implementation of BRI-related transport infrastructure, as well as the necessary investment costs associated with the projects. We discuss the measurement of these elements in details in sections 3.b. and 3.c. respectively.

First, as is apparent from the pricing equation (13) and the equilibrium trade shares (14), reducing trade costs κ_{ni}^{j} across many country-pairs and sectors is associated with an increase in trade flows through both a direct and an indirect channel. Equation (14) shows that, everything else constant, any reduction in trade costs leads to a proportional increase in trade shares by a factor θ^{j}. Moreover, because firms use inputs from other countries in their production processes, the reduction in trade costs is magnified by a reduction in the cost of the input bundle x_{n}^{j} as firms gain access to cheaper suppliers.

Second, as is apparent from the expression of expenditure shares (9), trade flows are governed by comparative advantage and firms optimize their sourcing decisions by comparing all possible options. Hence, whenever the decrease in trade costs (and, through input-output linkages, in production costs) is not uniform across country pairs and sectors, the new equilibrium not only features an increase in trade flows but also a reallocation of comparative advantage and the relative importance of specific trade partners is affected. As a result, the welfare gains that a given country can derive from common infrastructure investments depend on the distribution of trade cost reduction as well as all input-output linkages. Depending on the specific geographic location of the projects, this reasoning also means that the costs and benefits of common infrastructure investments can be very different – a point that will be more apparent when looking at the quantitative results in the next section.

Finally, we consider the interaction between changes in trade policy and in spending on infrastructure. This interaction can be more clearly seen in the price index of a given sector in changes in equation (13). A reduction in tariffs between country n and country i will affect, everything else constant, the level of trade openness in these countries, thus in the context of the price equation, π_{ni} becomes higher as tariffs are reduced between these two countries. On the other hand, infrastructure spending reduces the trade costs by reducing the shipment time as discussed above, thus $\hat{\kappa}_{ni}$ falls. Now it is clear that the impact of a decline in trade costs as a consequence of infrastructure spending on prices (thus real wages) will be higher the more open is the country, which is shaped by trade policy. In other words, an important insight from the model is that the impact of infrastructure on a given country will depend on its level of trade openness, which in turn is affected by trade policy.

3. Quantifying the effects of the Belt and Road Initiative

In this section, we calibrate our model to assess the impact of the transport infrastructure related to the Belt and Road Initiative. While the scope of the initiative is still taking shape, the BRI is structured around two main components, underpinned by significant infrastructure investments:[12] the Silk Road Economic Belt -the "Belt"- and the New Maritime Silk Road -the "Road" (Figure 1). The "Belt" links China to Central and South Asia and onward to Europe, while the "Road" links China to the nations of Southeast Asia, the Gulf countries, East and North Africa, and on to Europe. Six economic corridors have been identified: (1) the China-Mongolia-Russia Economic Corridor; (2) the New Eurasian Land Bridge; (3) the China–Central Asia–West Asia Economic Corridor; (4) the China–Indochina Peninsula Economic Corridor; (5) the China-Pakistan Economic Corridor; and (6) the Bangladesh-China-India-Myanmar Economic Corridor. The 71 economies highlighted in Figure 1 are those that are geographically located along the Belt and the Road and are considered as "BRI economies" in this paper.

a. Model parameters

The simple equilibrium structure of the model presented in the previous section allows to simulate counterfactuals with a large number of countries and sectors without any computational issue. This is important given the global nature of the shock we are studying: due to network effects, BRI transport infrastructure investments are expected to change bilateral trade costs among many country pairs in the world and not only for countries that will participate to the initiative. A key advantage from solving the model in relative changes is that it minimizes the data requirements to calibrate the model.

We use the newly available database in GTAP 10 to calibrate our model and consider a total of 107 countries and "regions" and 31 sectors.[13] To compute the model and perform counterfactual analysis, the following aggregates are used for all the countries considered in the analysis and for a constructed rest of the world, based on GTAP 10 data.

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[12] Transport projects are estimated to cover about one-quarter of total BRI investment (Bandiera and Tsiropoulos, 2019).

[13] See table B1 in appendix for the full list of countries and regions used in this paper.

- γ_n^j: share of value added in gross output by country and sector.
- $1 - \beta_n$: share of payment to labor in value added by country.
- γ_n^{jk}: input-output coefficients, consumption of materials from sector k in gross output in sector j.
- α_n^j: share of sector j in total final consumption in country n.
- $w_n L_n^j + r_n H_n^j$: value added by country and sector.
- X_{ni}^j: bilateral trade flows across countries for each sector (including all countries in the sample and a constructed rest of the world).
- X_{nn}^j: domestic sales, constructed as gross output minus total exports.
- t_{ni}^j: bilateral tariffs across countries for each sector (including all countries in the sample and a constructed rest of the world).
- G_n : spending in infrastructure by country estimated in the subsequent section.
- $\hat{\kappa}_{ni}^j$: proportional changes in trade costs associated with BRI transport projects, for each origin-destination-sector, estimated in de Soyres et al (2019), and discussed below.

We use the sectoral trade elasticities θ^j from Caliendo and Parro (2015) which were estimated for 20 tradeable sectors and which we map to our 31 sectors (Table 1). Their estimations are performed using trade and tariff data, without assuming bilaterally symmetric trade costs as is standard in the literature. Moreover, their method is consistent with any trade model that delivers a gravity-type trade equation.[14]

[14] We assume an elasticity 4.0 for the Oil, Gas and Coal industry to account for the fact that it takes time to renegotiate energy contracts and that some countries may not be able to source energy from alternative suppliers due to infrastructure constraints such as existing gas pipelines. We also performed alternative simulations with an elasticity of 51.08, which is the value estimated in Caliendo and Parro (2015) for "Petroleum" using their triple differentiation method. As expected, effects of BRI transport projects slightly increase at the aggregate level using this larger elasticity (GDP gains reach 3.0% for the world as whole, higher than our baseline results of 2.87% discussed below).

Table 1: Sectoral Trade Elasticities

Sector	Elasticity	Sector	Elasticity
Beverages and tobacco products	2.55	Machinery and equipment nec	1.52
Communication	7.07	Manufactures nec	5
Construction	4.55	Minerals nec	2.76
Dwellings	4.55	Meat products nec	2.55
Electronic equipment	10.6	Other Agriculture	8.11
Metal products	4.3	Other Services	4.55
Forestry	8.11	Transport equipment nec	4.55
Fishing	8.11	Paddy rice	2.55
Gas manufacture, distribution	5	Petroleum products, plastics and Chemicals	19.16
Leather and wood products	10.83	Paper products, publishing	9.07
Metals	7.99	Textiles	5.56
Dairy products	2.55	Transport	4.55
Motor vehicles and parts	4.55	Trade	4.55
Mineral products nec	2.76	Wearing apparel	5.56
Food products nec	2.55	Water and Electricity	4.55
Oil, Gas and Coal	4.0		

b. Estimated changes in trade costs

The Belt and Road Initiative covers a large number of transport projects in many countries. The consequences of implementing all those improvements is a priori very hard to forecast. We use the estimated decrease in trade cost associated with the BRI from de Soyres et al (2019). For clarity, we review here the methodology and main results.

In order to embrace the complexity of network effects while at the same time taking into account all planned BRI transport projects and all countries in the world, the analysis is based on an estimation of the reduction in shipping times between countries which are subsequently transformed into reduction in ad-valorem trade costs using Hummels and Schaur (2013) sectoral estimates of "value of time". We describe both steps in more details.

i. Estimated changes in trade shipping time

As a starting point, the method used in de Soyres et al. (2019) relies on a network model which takes into account in a precise way the current transportation network. This network is used to compute shipment times between all city-pairs using a shortest path algorithm. From this reference point, an "improved" scenario is simulated to account for the planned infrastructure projects linked to the BRI which enables the computation of the reduction in shipping times resulting from these projects.[15]

The analysis is carried out using a Geographic Information System (GIS) software which allows to precisely map the current transportation network and then to enrich it with the planned infrastructure improvements that can be linked to the BRI. A network solution involves finding the shortest path between two locations, where the length or cost of a path is the total accumulated shipping time computed along the optimal path. In this context, only rail and maritime links are considered.

The nodes of the network, which serve as both origin and destination in the analysis, are cities with population greater than 500,000[16] as well as the two most populous cities in each country (data permitting). This creates a total of 1,000 cities and includes 34 cities with reported population less than 50,000. The network is solved for each origin-destination pair. To obtain more accurate time estimates, georeferenced data are complemented with proxies for port quality using data from Slack, Comtois, Wiegmans and Witte (2018) on the amount of time spent in port by vessels. Additional data on border delays related to border compliance come from the "trading across borders" section in the World Bank's Doing Business Database.[17]

ii. From shipping time to trade costs

Overall, shipment time is only a fraction of trade costs, which also contains the actual transportation cost as well as the tariffs and other monetary charges that can be applied between respective countries. The previous section focused on the decrease in trade costs that can be achieved from a reduction in shipping time. One now needs to account for the fact that trade costs encompassing these other elements. Total trade costs can be defined as follows:

Trade Cost = tariff + transport + time cost.

Assuming that both tariffs and transportation costs are unchanged, we compute the decrease in total trade costs that can be expected from the sheer decrease in shipping time. As

[15] The list of projects considered as well as the associated assumptions for the computation of shipment times are presented in de Soyres et al (2019).

[16] Population sources are https://www.citypopulation.de/world/Agglomerations.html and http://data.un.org/Data.aspx?d=POP&f=tableCode%3A240

[17] For any border, we use the data on "Border Compliance" and the total delay is assumed to be the sum of export time from the exporting country and the import time from the importing country. We do not include documentary compliance, as it does not relate to travel time. All data are available at: http://www.doingbusiness.org/data/exploretopics/trading-across-borders.

discussed in de Soyres et al. (2019), the (population weighted) shipping time between country-pairs can be transformed into an ad-valorem equivalent using estimates from Hummels and Schaur (2013) on the "daily value of time" at the sector level. These estimates are added to transport costs and data on tariffs from GTAP to obtain country pair-sector values of trade costs.[18]

Table 2 presents the results for two scenarios, referred to as the "lower-bound" and the "upper-bound". The "upper-bound" scenario allows for changes in transportation mode due to the new infrastructure while the "lower-bound" scenario assumes that switching mode of transportation is difficult -allowing for modal changes lower than 5 percent with respect to the pre-BRI modes of transport. The decrease in total trade costs associated with the new BRI projects ranges between 1.05 and 2.19 percent. For some country-pairs this decline is zero, while the maximum change ranges between 61.52 and 65.16 percent.

Table 2:Percentage decrease in trade costs due to the BRI

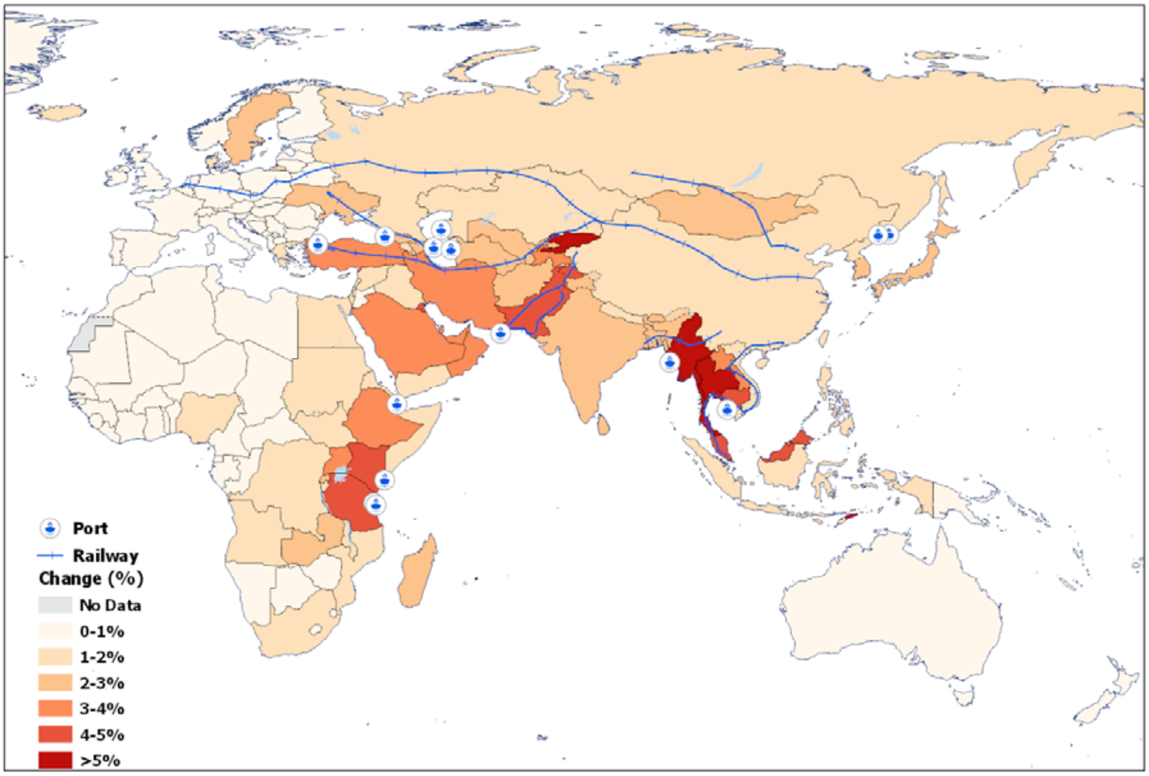
% decrease in trade cost	Min	Max	Mean	Std. Dev
		World		
Lower Bound	0.00%	61.52%	1.05%	2.43%
Upper Bound	0.00%	65.16%	2.19%	3.40%
		BRI Countries		
Lower Bound	0.00%	61.52%	1.50%	3.07%
Upper Bound	0.00%	65.16%	2.81%	4.18%

Note: Summary statistics across all country-pairs and sectors in the world.

There are many ways to present the results of such analysis. One possible aggregation scheme consists of weighting all destinations by import or export flows and hence understand the potential gain from the perspective of a global buyer or seller in each country. Focusing on the upper bound results, Figure 2 presents such an aggregation and reports the gains weighted by import flows, so that the results can be interpreted through the lenses of a firm that sources its inputs from abroad. They indicate that larger reductions in trade costs are expected along the overland and maritime BRI corridors and that BRI projects lower trade costs also for a number of countries where transportation infrastructure are not built or improved.

[18] These time elasticities constitute the most comprehensive and detailed estimates of value of time. In their work, Hummels and Schaur (2013) overcome several endogeneity issues faced by previous work, including unobserved quality and selection issues related to endogenous firms' exports decision. Moreover, owing to the rich disaggregation of these estimates, we are able to account for sectoral differences in the trade flows sensitivity to shipment time, which is quantitatively significant in a model that accounts for each country's sectoral distribution and input-output linkages. However, such value of time also come with limitations, including the fact that estimates are entirely based on US data, whereas it is possible that time sensitivity of consumers and firms include country-specific factors.

Figure 2: Average decrease of trade costs per country – Upper Bound.



Note: For each country, all destinations are weighted by import flows.
Source: de Soyres et al (2019).

c. Estimated infrastructure costs

There is little publicly available information on the terms and conditions of BRI projects. In order to compute the total costs associated with BRI transport infrastructure, we combine information from World Bank country teams, which draw from publicly available sources on the costs of a small subset of BRI projects, with a bottom-up approach based on the projects' characteristics and assumptions of construction costs. Specifically, we first start by computing the length (in km) of each new rail junction, improvement of existing rails, tunnels, canals and bridges. Then we use the assumptions presented in Table 3 to quantify the cost for infrastructure projects for which we do not have country specific information, which are the large majority of cases. The cost per kilometer of improvement of existing rail is based on the expected rehabilitation and upgrade cost of the Karachi-Lahore Peshawar railway track. Assumptions on the cost of tunnels and bridges are based on Ollivier, Sondhi, and Zhou (2014).

Table 3: Assumptions in the construction of Infrastructure Costs

Project type	Cost per unit million of USD (per km)
new rail	12.14
improvement of existing rail	4.37
tunnel	11
canal	30
bridge	10
new port	case-by-case basis
improved port	case-by-case basis

Based on these assumptions, Table 4 presents the total estimated costs of BRI transport infrastructure in each country.

Table 4: Estimated Total Costs per country (million of USD)

Country	Total Country Cost million of USD	Country	Total Country Cost million of USD
Afghanistan	12,252.14	Pakistan	49,301.82
Azerbaijan	2,262.44	Russian Federation	18,065.90
Bangladesh	6,880.27	Singapore	303.57
Cambodia	2,039.68	Tajikistan	3,480.29
China	63,706.51	Thailand	11,798.27
Georgia	5,146.44	Turkey	1,946.71
Greece	-	Turkmenistan	15,155.30
India	3,400.00	Uzbekistan	5,780.94
Iran, Islamic Rep.	10,621.36	Vietnam	8,586.71
Kazakhstan	21,305.71	Djibouti	580
Korea, Dem. People's Rep.	-	Ethiopia	9,131.43
Kyrgyzstan	5,391.43	Indonesia	582.86
Laos	6,528.57	Kenya	23,597.86
Malaysia	12,997.86	Sudan	4,310.71
Mongolia	35,515.57	Tanzania, United Republic of	1,100.00
Myanmar	26,397.86		
TOTAL Cost		**368,168.23**	

In order to use these estimates in the context of our static model, we cannot simply use the total costs computed above and compare those to a single year of annual gain. Indeed, the model is calibrated using yearly data (trade flows and GDP are annual) and hence total consumption levels found in our simulated results are comparable to one year of consumption.

One way to compare the cost and benefits of investing in transport infrastructure using such a static model could be to compare the one-time initial cost payment to the present discounted value of the benefits that will be felt from the investment onward. Let G_n be the total annual welfare gain for a country in terms of real consumption, $G_n = \frac{I_n}{P_n} - \frac{I'_n}{P'_n}$, and D_n the one-time investment cost. Assuming a constant discount rate r, we could compute the net gain as the difference between the net present value of all gains and the one-time initial cost:

$$\sum_{i=1}^{+\infty} \frac{G_n}{(1+r)^i} - D_n = \frac{G_n}{r} - D_n$$

However, such an approach would assume that the whole cost of infrastructure is paid in full in the first year and the benefits are felt thereafter. In our model, this would imply setting both the annual investment (D_n^{annual}) and the annual lump sum tax for the household (τ_n^L) to zero and assuming that investment occurs *before* solving for the equilibrium. By doing this, however, we would not properly account for the interaction between the investment cost in the household budget constraint and the equilibrium allocation: since countries have different consumption baskets and sectoral distributions, it is important to be able to incorporate the investment cost within the annual equilibrium structure described above.

To take into account the costs of infrastructures in a way consistent with the static model and its annual equilibrium, we use an "annualized" cost which allows us to compare one year of household revenues to one "yearly equivalent" of the investment cost. To do so, we simply assume that the costs are paid through a perpetuity with interest rate r. The equivalent annuity for country n, denoted as D_n^{annual} and paid by the consumer as lump sum τ_n^L, is then computed as:

$$D_n = \sum_{k=1}^{+\infty} \frac{D_n^{annual}}{(1+r)^k} \Longrightarrow D_n^{annual} = \tau_n^L = r \times D_n$$

Assuming an interest rate r of 2.5 percent, the total annual cost of the BRI would be around \$9.2 billion. China, the country with the highest infrastructure costs, is assumed to sustain annual costs around \$1.6 billion which would increase to \$3.9 billion in the case it pays 30 percent of the total cost in other BRI countries in the form of equity investment. These country-specific annualized costs τ_n^L are then included in the household's budget constraint and in the computation of the counterfactual equilibrium as described by equations (16) to (21). Proportional welfare gains from the initiative are given by $(\frac{I_n'}{I_n})/\,\hat{P}_n$.

d. Results

Based on the estimated reduction in trade costs as well as the infrastructure costs associated to BRI transportation investment, we can compute a counterfactual equilibrium of the model and derive predictions in terms of trade flows and production at the sectoral level for all countries. As described below, our results for BRI transport investments feature overall welfare gains but also important heterogeneities across countries.

Two related elements are worth emphasizing to understand the results obtained with our approach. First, input-output linkages across and within countries propagate and amplify the decrease in production costs that can be associated with a decrease in trade cost. This is because, given the common nature of the shock (i.e. infrastructures are built in multiple countries), the BRI is associated with a decrease in trade costs between many country-pairs in the world and, in some cases, within countries. Second, it is important for our quantitative exercise to keep a very disaggregated version of the world with many countries. Indeed, every time one aggregates two countries that will experience decrease in trade costs between one another, one risks of not accounting for some gains that are linked with the BRI. This is especially important because we are not studying a local policy change which would leave most country-pairs' trade costs unchanged, but rather a change in the overall transportation network. In this sense, using a quantitative framework that can account for input-output linkages while being parsimonious enough to be calibrated and simulated with many countries is quantitatively relevant.

i. GDP Changes

We first present the results of the effect of BRI transport projects on GDP.[19] These results should be interpreted as the long-term effect of changes in trade costs only. The model used in the simulation features consumption gains from reduction in trade costs for final goods but also production gains that are transmitted through trade in intermediate inputs and sectoral linkages which lead to reductions in firms' production costs. An important caveat is that the counterfactual scenarios abstract from any changes in other costs such as those related to factor movements or

[19] GDP contains both payment to labor and payment to the fixed factor, deflated by the consumption price index. In our case, firms' optimality in the firms' decision imply that the relative change in real wages and real interest rate are equalized. Moreover, with fixed factor supply (both labor and land/structure are fixed), proportional change in GDP is simply a weighted average of proportional changes in real wage and real interest rate. Hence, because those two things are equal, it can be noted that proportional changes in (i) GDP, (ii) real wage and (iii) real interest rate are all equal.

technological transfers which are likely to be affected by changes in shipping time as well as from congestion frictions of the transport network.

Figure 3 presents the results for the lower bound scenario in which modes of transport are relatively fixed (country-level results are reported in Annex Table C1). Panel A plots the distribution of GDP gains. The BRI is expected to increase real wages in all countries in the world. The distribution for BRI economies is shifted to the right of the distribution of the gains for the world. The median impact for BRI economies is 1.59 while it increases to 2.99 for BRI core countries[20] -i.e. those that are expected to build rail and port projects.[21] The average increase is around 1.46 percent with increases in real GDP of up to 6.9 percent for Cambodia.

The impact for BRI countries varies by region and income group. BRI upper middle income and low-income economies are expected to benefit from the infrastructure improvement the most. The results for upper middle income are driven by China's improvement in access to foreign markets, estimated to increase its GDP by 2.48 percent, while the impact for low-income countries is driven by Tanzania with an estimated gain of 2.87 percent. Similarly, the results for Sub-Saharan Africa are high because of the new ports in Tanzania and Kenya that improve substantially the connectivity of those two countries to other BRI countries and the rest of the world. East Asia and Pacific and Europe and Central Asia regions, the most active in terms of BRI projects, are expected to increase their GDPs by 2.14 and 1.46 percent respectively.

[20] See table B1 in appendix for the list of BRI core countries and see de Soyres et al. (2019) for the full list of BRI projects.

[21] To compute the weighted averages of the gains, we use pre-BRI GDPs as weights.

Figure 3: Impact of BRI Infrastructure improvement on GDP- Lower Bound

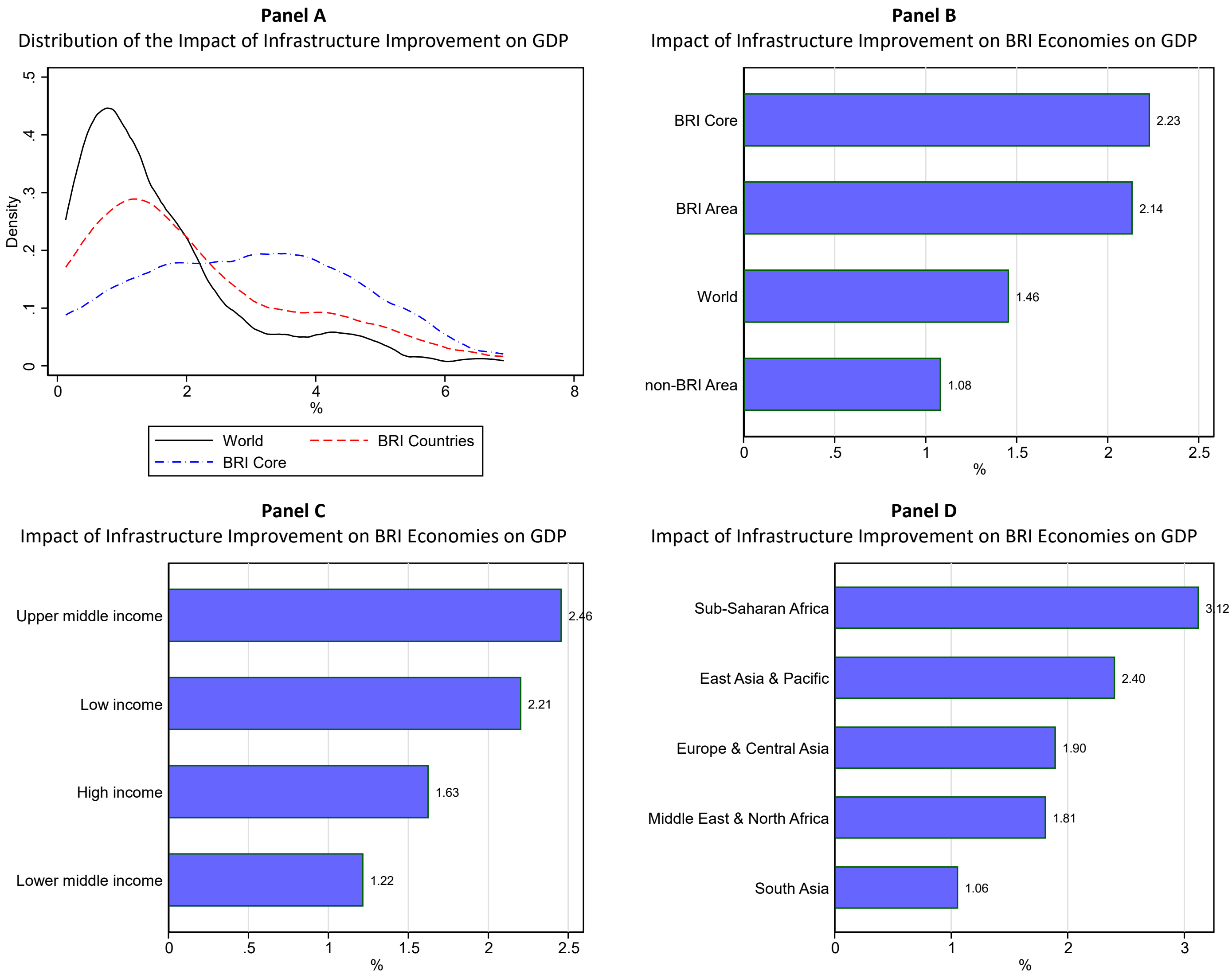
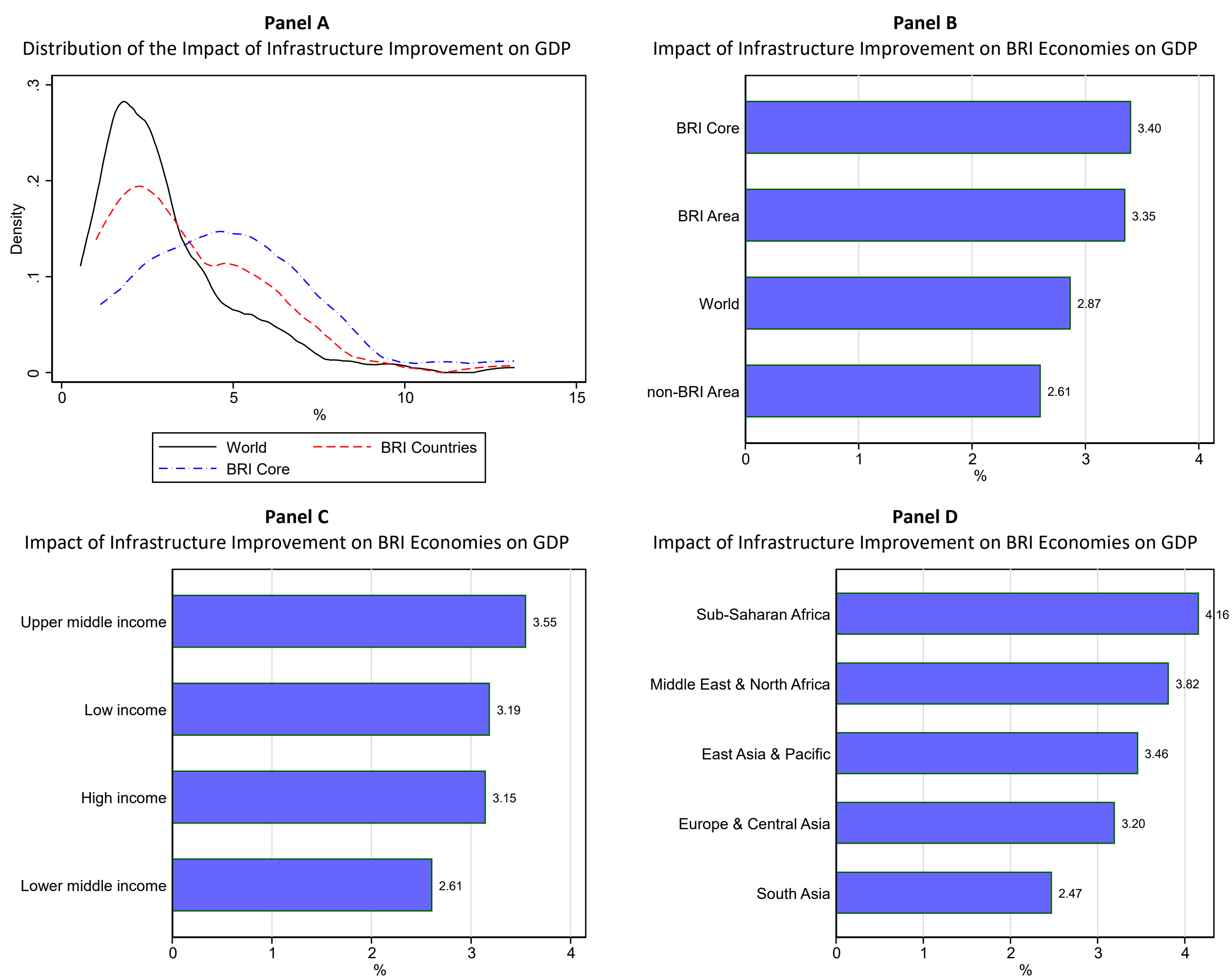


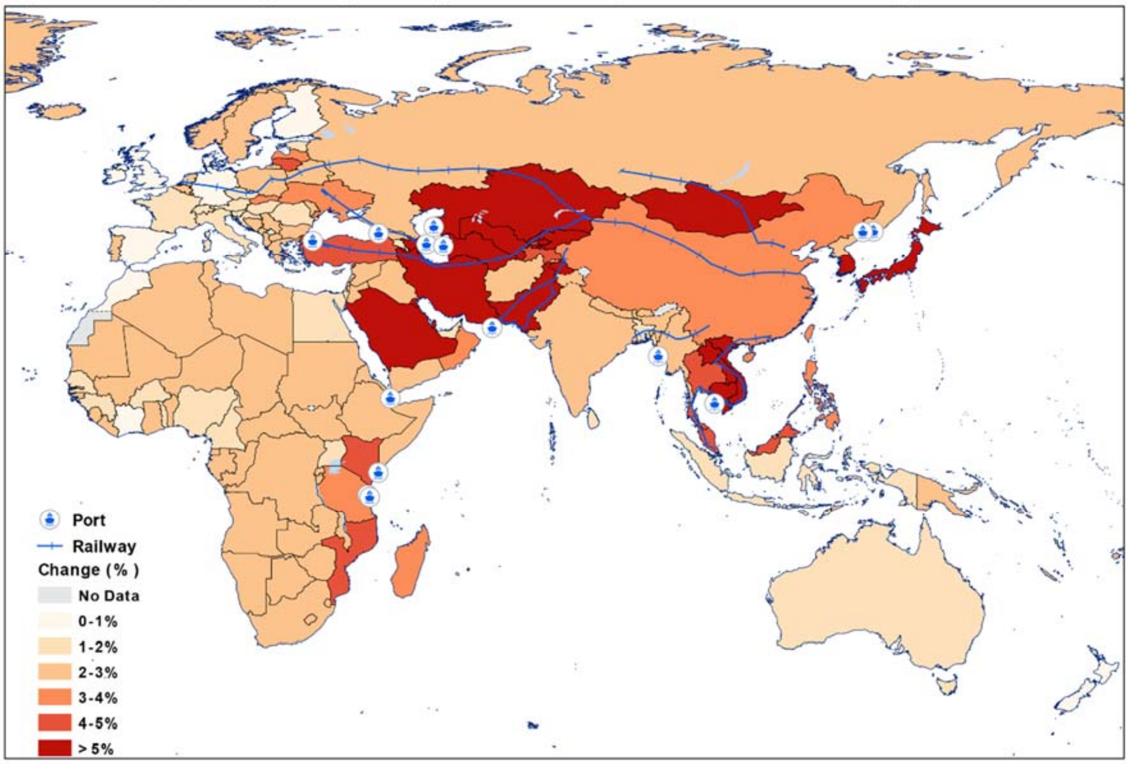
Figure 4 presents the results from the upper-bound scenario that allows for switches in mode of transport. The GDP impact in the upper bound are larger for both BRI and non-BRI economies. The median effect increases by around 50 percent for BRI economies while it more than doubles for non-BRI economies from 0.98 to 2.27. In terms of regions, Middle East and North Africa is estimated to increase its average gains by a factor of two with respect to the lower bound scenario. The gains are driven by large increases in oil-rich economies for which demand is increasing due to the expansion of economic activity in other BRI countries. In terms of country-income groups, this scenario suggests a more uniform distribution of the GDP gains.

Figure 4: Impact of BRI Infrastructure improvement on GDP - Upper Bound



The impact of infrastructure improvements on GDP is heterogenous across countries. Figure 5 shows that the impact is larger for countries where BRI transport infrastructure projects (i.e., rails and ports) are planned and for their neighbors that benefit from a positive spillover effect thanks to their proximity to the new infrastructure. Central and Southeast Asian economies are expected to experience the largest GDP changes as a result of the initiative. The new ports in Africa are expected to bring large benefits especially for Kenya, Mozambique and Tanzania.

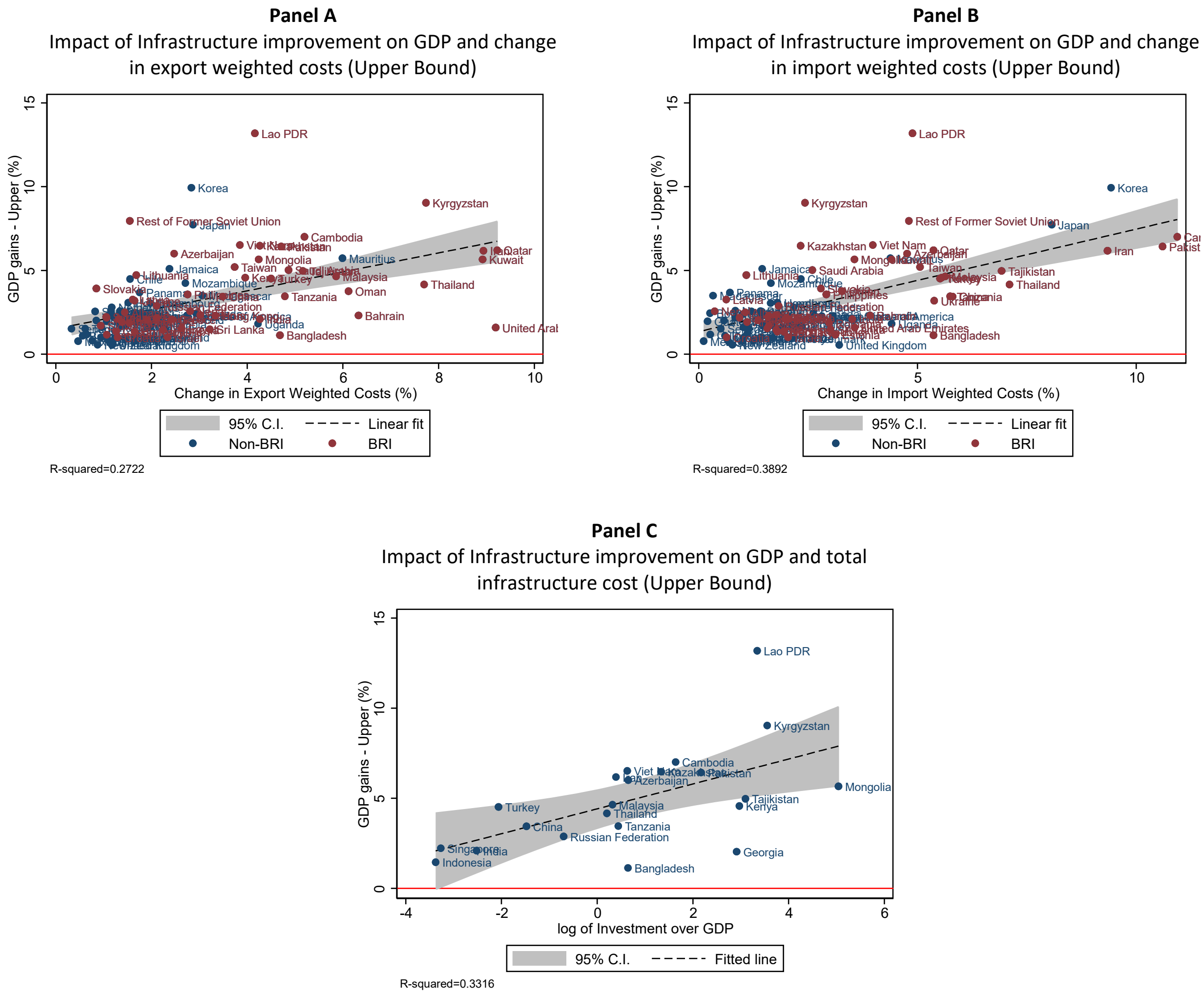
Figure 5: Map of the effects of BRI Infrastructure improvement on GDP - Upper Bound



Note: The map shows the proposed railway and port projects part of the BRI. Results for the rest of the world are used for countries not listed in Annex Table B1.

To better understand the impact of the BRI on GDP changes, Figure 6 plots the gains against the reduction in trade costs and the expected infrastructure investment. The top panels show a positive relationship between the reduction in trade weighted costs and GDP gains. Changes in import weighted costs explain almost 40 percent of the variation in GDP gains while changes in costs to export destinations account for less than 30 percent. The large gains for non-BRI high income economies located in East Asia are associated with large changes import weighted costs. The proximity of these countries to BRI economies allows them to take advantage of productivity improvements in the region. For instance, firms located in Japan and Korea could benefit from the access to better and cheaper inputs originating in BRI economies that in turn would increase their competitiveness in third markets. Finally, for BRI core economies GDP gains are positively correlated with the size of the expected investment in BRI projects (Panel C). Among the outliers, Bangladesh and Georgia are expected to gain much less than other countries with similar investment size over GDP. Conversely, the gains for Lao PDR are much larger than the ones for Mongolia which is expected to sustain a higher investment.

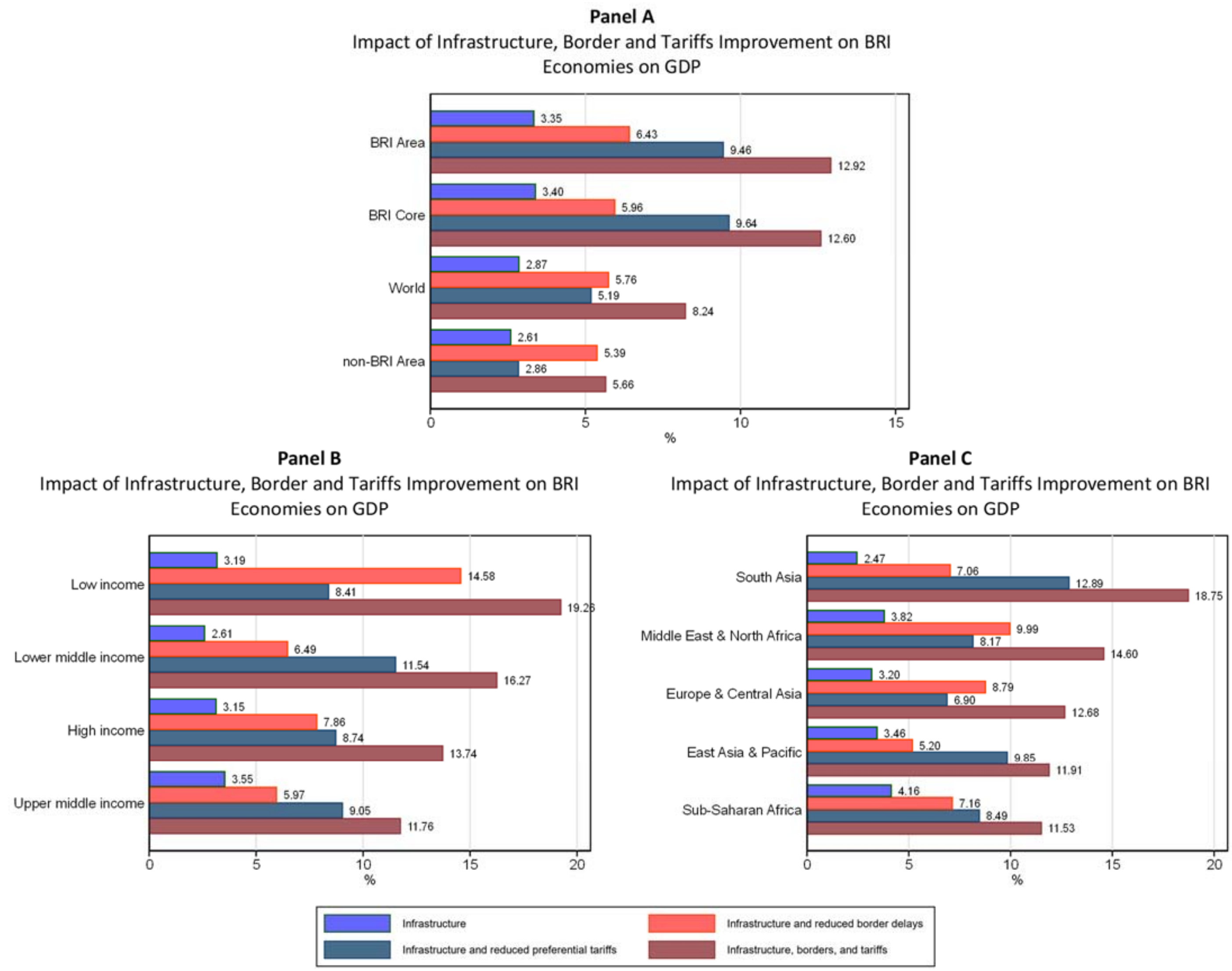
Figure 6: Determinants of GDP Gains - Upper Bound



The impact of a more ambitious set of reforms could magnify the gains from the new infrastructure network. Figure 7 presents the results from complementary policies related to border delays and to tariff reduction among the BRI economies. For instance, if in addition to an improved infrastructure network also border delays were reduced by half, BRI economies could double the GDP gains coming from infrastructure investment alone. As all countries, BRI and non-BRI, are subject to border delays we find that non-BRI economies benefit as well from trade facilitation reforms. Low income countries, which trade intensively with countries or tend to have long border delays, would disproportionately benefit from better border management. Better border management would allow firms located in low income countries to access cheaper inputs increasing their competitiveness in foreign markets. As a consequence, demand for labor would increase pushing nominal wages up. Finally, a more efficient use of intermediate inputs and lower transport costs would lead to a decrease in prices of final goods.

As a second exercise, we simulate a 50 percent reduction in applied tariffs among BRI economies. Average tariffs in BRI countries are relatively high compared to tariffs in advanced economies. Applied tariffs in BRI countries vary between around 14 percent in Sub-Saharan Africa and 2 percent in East Asia and Pacific compared to applied tariffs of below 1 percent in G7 countries. Figure 7 shows that trade policy could have a substantial effect on countries in South Asia that could increase the impact of infrastructure improvement alone by a factor of 5. Interestingly, countries located in the Middle East and North Africa and in Europe and Central Asia would benefit more by combining infrastructure investment with trade facilitation polices rather than combining it with trade policies. This result is explained by relatively high border delays in these regions and by the fact that they rely disproportionately more on non-BRI countries in terms of inputs for their production. The effect of combining both a reduction in preferential tariffs and border delays would increase the benefits for both BRI and non-BRI members more than individual complementary policies alone.

Figure 7: Impact of Infrastructure and Complementary Policies on GDP – Upper Bound

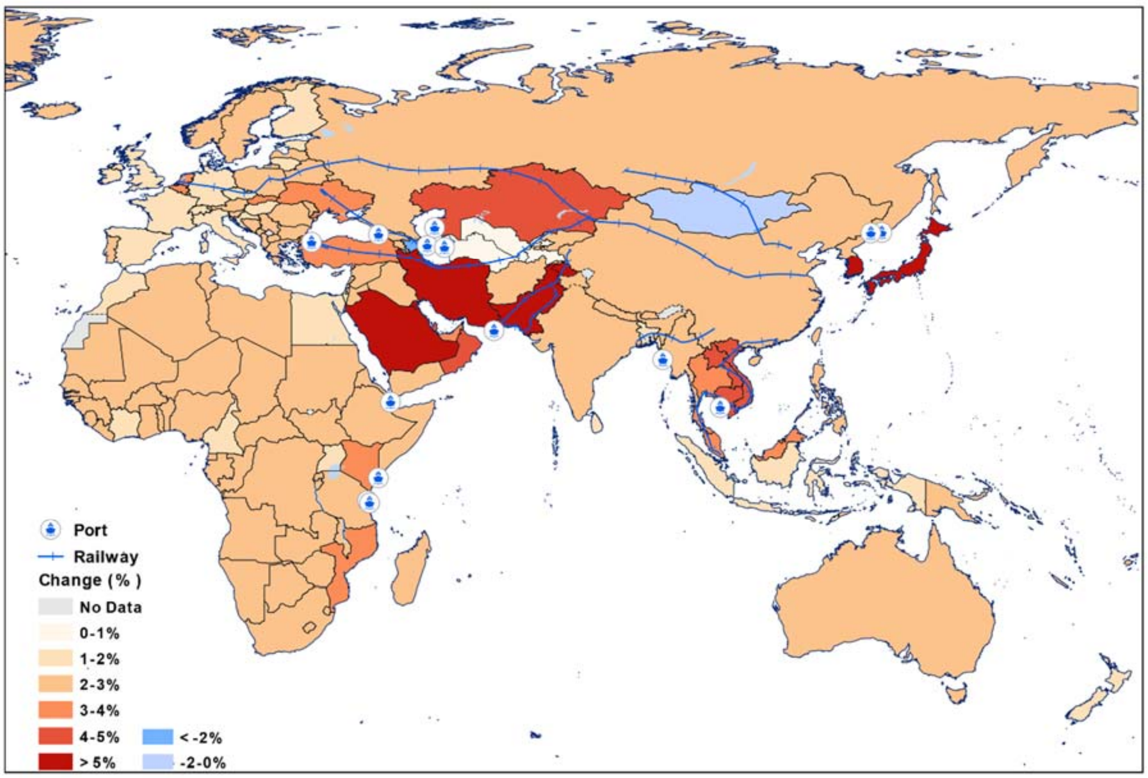


ii. Welfare Changes

We next look at welfare, defined as real consumption, which is equal to net household revenues divided by the relevant consumption price index. It should be noted that total revenue takes into account payment to labor, revenues derived from the portfolio shares and from import tariffs, but also takes into account the reduction of disposable income due to the (annual) estimated cost of the transport infrastructures presented in Table 4.[22]

Once the cost of the infrastructure projects is factored in, the impact of the BRI could be negative on the welfare of some economies (Figure 8). In absence of complementary policies or intra-BRI transfer mechanisms, the large cost associated with transport infrastructures is expected to decrease welfare for Azerbaijan and Mongolia in the upper-bound scenario. The changes in welfare for non-core BRI economies are similar those in GDP as these countries do not contribute to the cost associated with the infrastructure projects but benefit from them. Notable examples are Japan, South Korea and Saudi Arabia with welfare increase greater than 5 percent.

Figure 8: Map of the effects of BRI Infrastructure improvement on Welfare - Upper Bound



Note: The map shows the proposed railway and port projects part of the BRI. Results for the rest of the world are used for countries not listed in Annex Table B1.

[22] It is worth noting that welfare differs from real GDP because of two main reasons. (1) Some of the countries' income is not used for consumption but for the investment associated with BRI transport projects (this applies only to BRI core countries); and (2) the model features trade imbalances (through the difference between payment and income from the global portfolio) implying that some countries consume more (trade deficit) or less (trade surplus) than their total income.

Figure 9 shows the welfare impact of the different simulations for the upper-bound scenario (country-level results are presented in Annex Table C2). Overall, welfare results are similar in magnitude to the GDP effects. The main difference is that changes in welfare are smaller than those in GDP for BRI countries, especially BRI core countries that pay the annualized cost of the BRI infrastructure. The expected impact for BRI core countries is 18 percent lower in the improved infrastructure network scenario and 20 percent lower when we assume a 50 percent reduction in tariffs which lowers the revenue coming from import tariffs. The impact for non-BRI economies is higher as they do not bear the cost of the new infrastructure.

Figure 9: Impact of Infrastructure and Complementary Policies on Welfare – Upper Bound

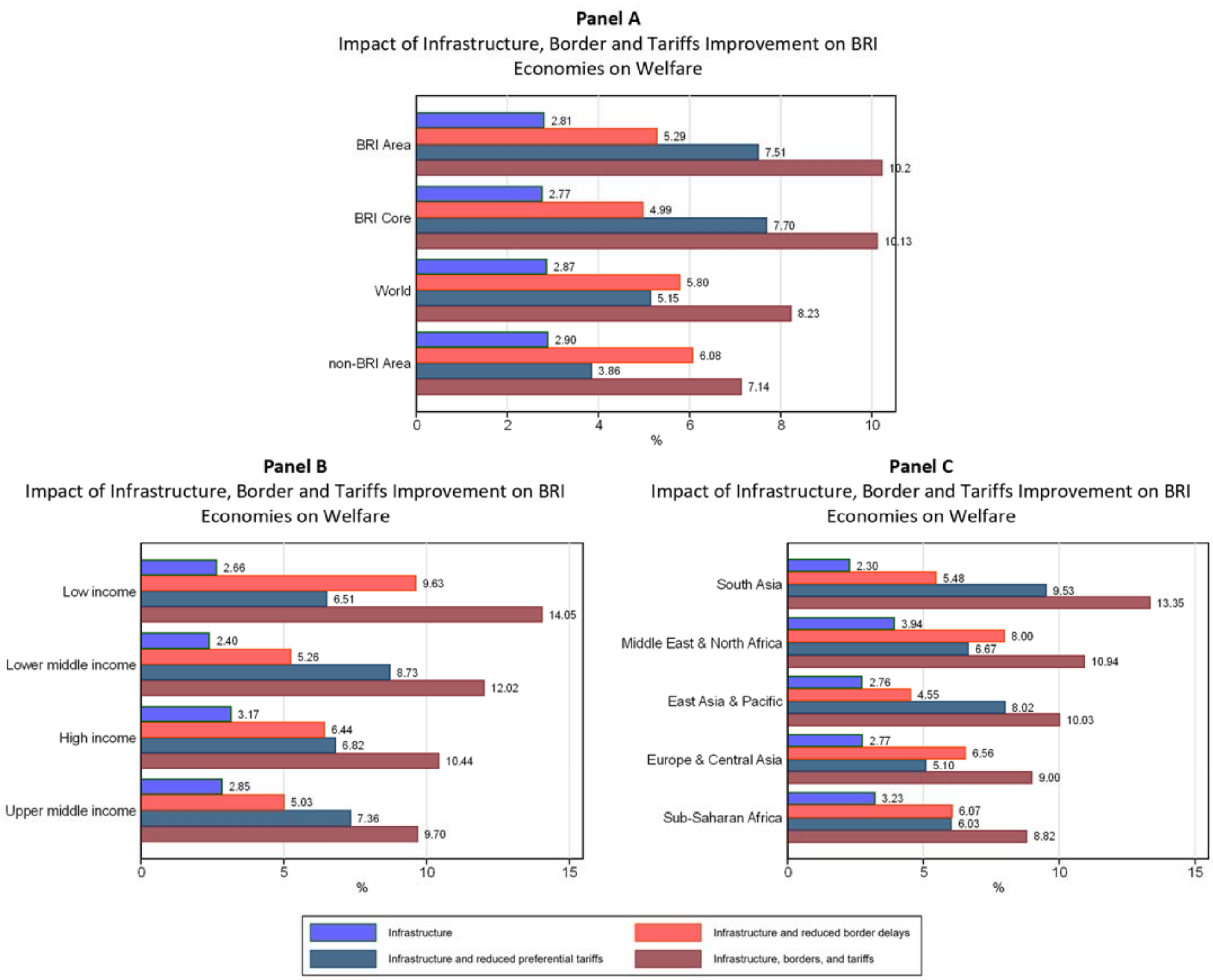
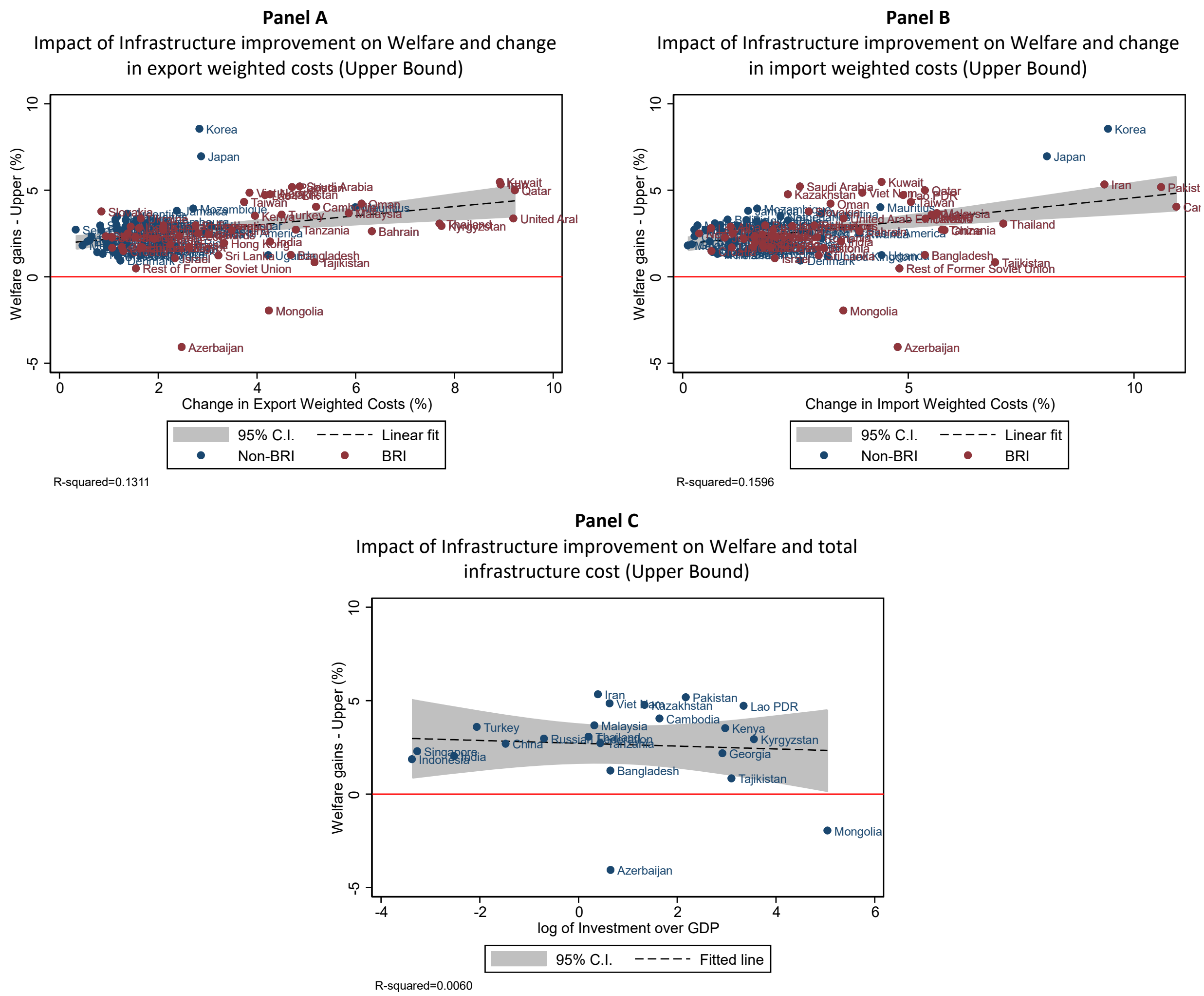


Figure 10 presents correlations between welfare gains and changes in trade costs and relative investment size. Changes in trade costs explain around 15 percent of the variation in welfare changes, less than half of what we find for GDP gains. Once we factor in the cost of the infrastructure, the gains for BRI economies are much smaller and, in a few cases, even negative. For instance, the welfare gains for Lao PDR, which is expected to sustain a large investment relative to the size of its economy, are around one-third of the GDP gains. Countries along BRI corridors that are not sustaining any of the infrastructure costs such as Saudi Arabia, Kuwait, and Qatar are expected to increase welfare and GDP by similar magnitudes. For BRI core countries, Panel C shows that there is low correlation between welfare gains and infrastructure investment over GDP and that this relationship is slightly negative – countries that invest more are expected to have lower welfare gains. These results highlight the strong spillover effects of infrastructure investment where the size of the investment is not a good predictor of gains.

Figure 10: Determinants of Welfare Gains – Upper Bound



Indeed, because trade gains are not commensurate to project investment, three economies (Mongolia, Azerbaijan and Tajikistan) are shown to have a net welfare loss due to the high cost of infrastructure relative to the trade gains in the lower-bound scenario and two economies (Mongolia and Azerbaijan) in the upper-bound scenario (see Figure 8 and Annex Table C2). Complementary reforms aimed at reducing border delays and preferential tariffs could, however, improve the integration gains from transport projects leading to net welfare gains for these countries as well. A caveat is that the analysis assumes that the final cost of the transport projects is not higher than the expected cost, which is rarely the case for large infrastructure projects (e.g. Bandiera and Tsiropoulos, 2019) and that there are no other governance problems (i.e. corruption, failures in public procurement) that would risk to further inflate the cost of infrastructure.

iii. Trade

We now discuss the changes in real trade flows following the implementation of BRI projects. Using equations (18) and (19) we can derive information on $\hat{X}^j_{ni} = \hat{\pi}^j_{ni}\hat{X}^j_n$ which represents the changes in nominal value of trade flow (net of tariffs) from country *n* to country *i* in sector *j*. Next, we need to construct changes in *real* trade flows and deflate the change in nominal values with the change of the relevant price indices. In Caliendo and Parro (2015), tariff changes only impact the input bundle and affect all exporters of intermediate goods proportionally. Hence, changes in input costs $\hat{x}^j_n$ precisely measure the change in trade prices. In our case, the shock we consider actually impacts the *non-tariff* part of the trade costs and has a direct impact on trade prices on top of the effect through input cost. Hence, we need to account for that as well when computing the relevant price index and we deflate nominal values by $\hat{x}^j_i\hat{\kappa}^j_{ni}$.

The BRI is expected to reshape trade relations among participating countries with each other and with the rest of the world. High trade times before the BRI contributed to keep intra and extra-regional trade low for these economies. The model predicts that BRI transportation infrastructure projects will increase intra-BRI trade by 7.2 percent. Changes in trade flows will vary by region, depending on how trade costs are affected by the new infrastructure and on the structure of the economy. Table 5 presents the changes in trade among BRI countries and between these economies and non-BRI countries.

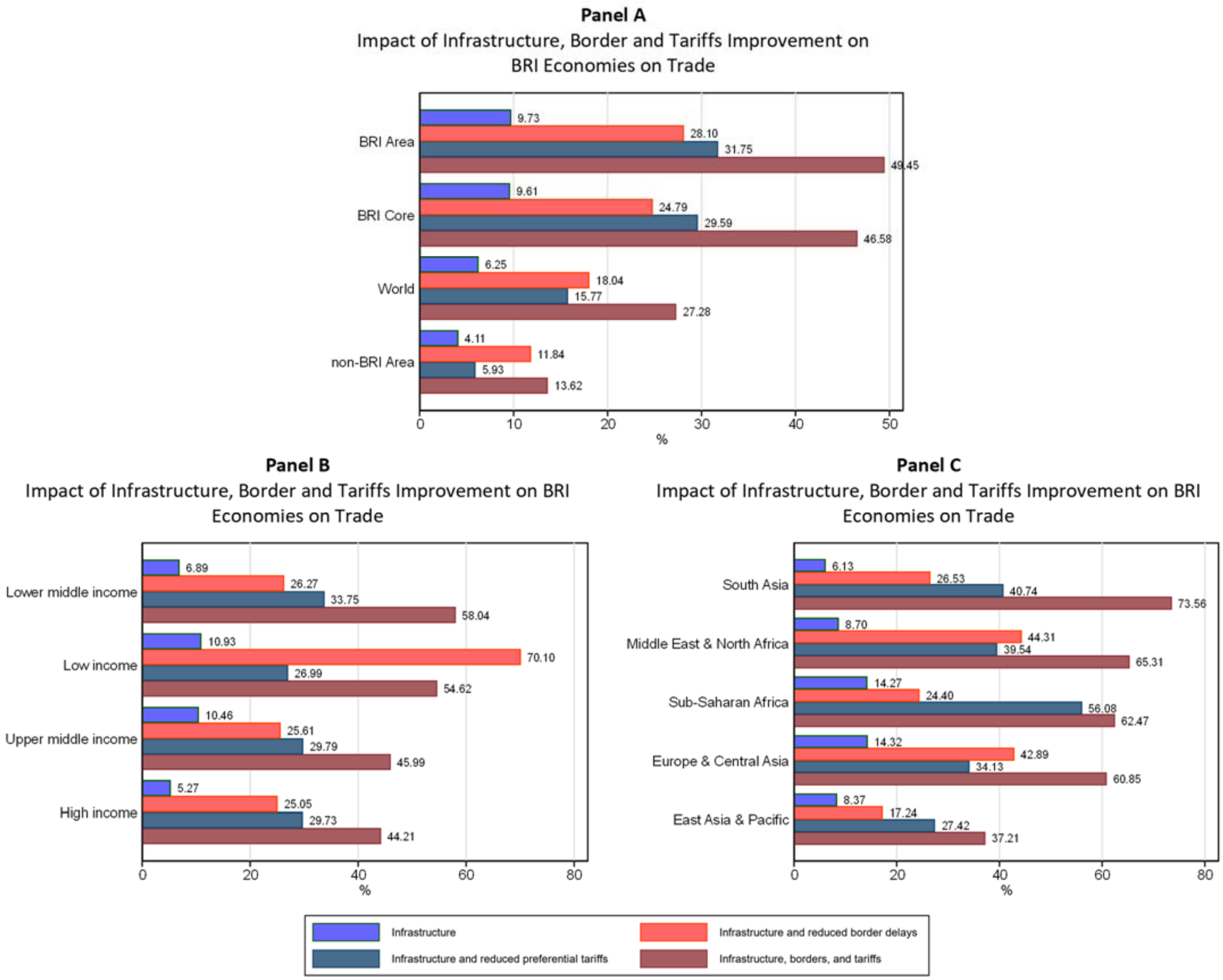
Estimates suggest that all regions, except the Middle East and North Africa, expand their exports to East Asia and Pacific, reflecting the large increase in imports of China and, to a smaller extent, of other economies in the region such as Thailand. The improved connectivity will also allow East Asia and Pacific countries to expand their exports to other BRI regions most notably the Middle East and North Africa and Europe and Central Asia and to themselves reflecting an intensification of regional value chains. Other large changes in bilateral flows include increased exports from the Middle East and North Africa region to South Asia and Europe and Central Asia. This result is explained by firms' access to cheaper inputs from other BRI economies which increase the competitiveness in other markets. Finally, this channel is particularly important for firms located in Europe and Central Asia that expand their exports to non-BRI countries.

Table 5: Changes in Trade Among BRI Countries

	from BRI to BRI	East Asia and Pacific	Europe and Central Asia	Middle East and North Africa	South Asia	Sub-Saharan Africa	non-BRI Area
Exporters	East Asia and Pacific	5.88	8.63	10.98	0.75	-4.05	9.86
	Europe and Central Asia	0.27	9.59	13.69	0.29	23.82	18.35
	Middle East and North Africa	-1.76	37.87	3.76	25.90	8.21	8.59
	South Asia	5.98	13.86	8.52	1.12	-1.45	5.65
	Sub-Saharan Africa	16.95	22.37	11.00	17.43	-0.28	15.03

Complementary policies that promote trade facilitation and reduce preferential tariffs among BRI economies would boost their exports. A reduction in border delays would magnify the effects of BRI transportation projects on exports from BRI economies by a factor of three (Figure 11, Panel A). Specifically, if in addition to an improved infrastructure network, border delays were reduced by half, BRI economies could experience export growth of 28.1 percent. This effect is not surprising given the high delays at the border in many BRI economies. Indeed, Panels B and C show that the largest effects would be for low income economies and for Central Asian countries that tend to experience larger border delays. The impact of infrastructure projects could be magnified by a reduction in tariffs among all BRI economies which would create more trade especially among participating countries. Not surprisingly, regions with higher tariffs, such as South Asia, would experience larger trade effects under this policy scenario.

Figure 11: Impact of Infrastructure and Complementary Policies on Trade – Upper Bound

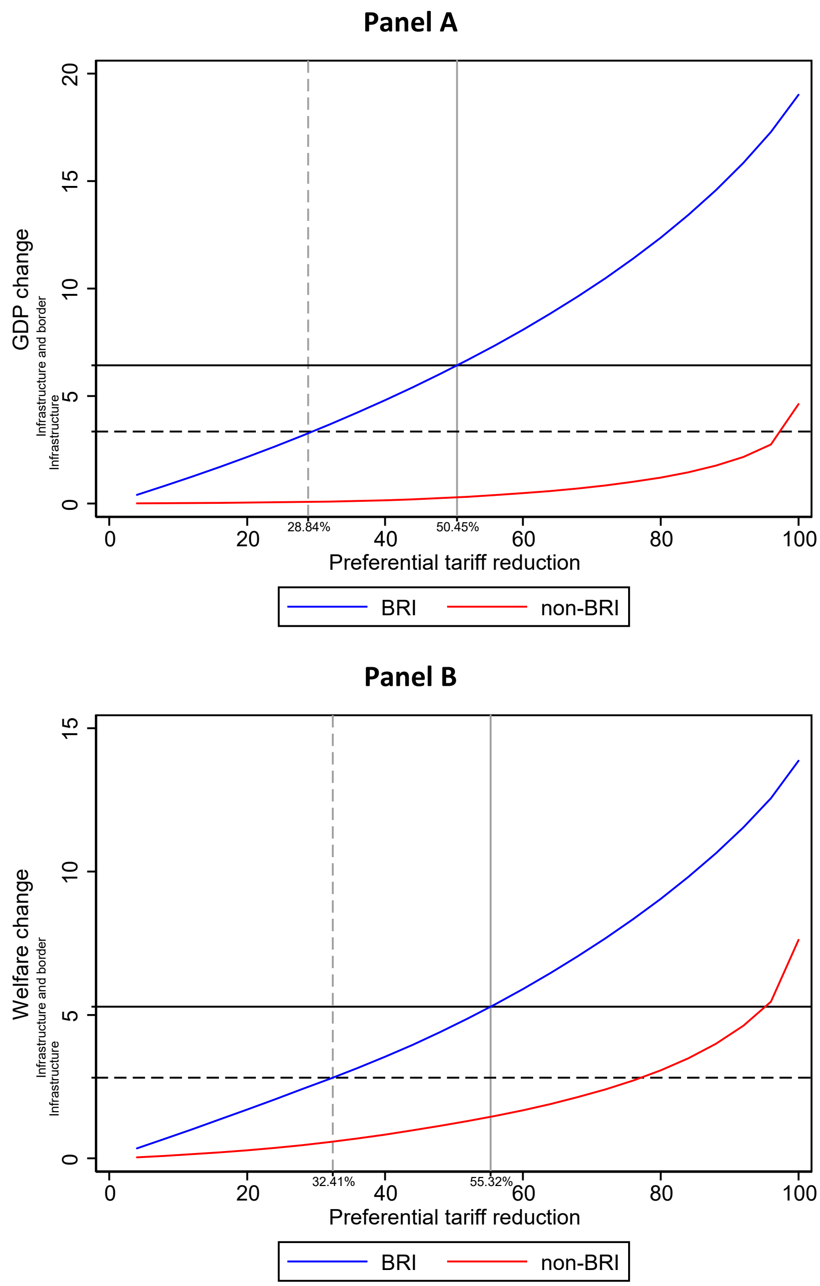


iv. Tariff equivalent of the BRI

What is the uniform tariff reduction among BRI countries that would deliver an equivalent change in GDP or welfare of BRI transport projects? In other words, in this section we replicate with trade policy only the overall effect in terms of GDP or welfare of the BRI infrastructure on BRI countries. Figure 12 Panel A, shows that BRI countries would need to reduce preferential tariffs by 28.8 percent to replicate the overall GDP impact of the new BRI infrastructure. Replicating the impact of the new infrastructure and trade facilitation policies would be much more ambitious as it would require tariffs to be reduced by around 50 percent.

In Panel B we take into account the loss in revenue due to trade liberalization and match the welfare impact of the BRI, we find that the uniform tariff reductions increase to 32.4 and 55.3 percent in the case of infrastructure and infrastructure and trade facilitation, respectively. Finally, we find that impact of the BRI infrastructure and trade facilitation policies in BRI countries would have a large positive impact on non-BRI members which would not be attainable by a reduction in preferential tariffs in BRI countries.

Figure 12: Impact of Tariff Reductions on GDP and Welfare of BRI and non-BRI countries

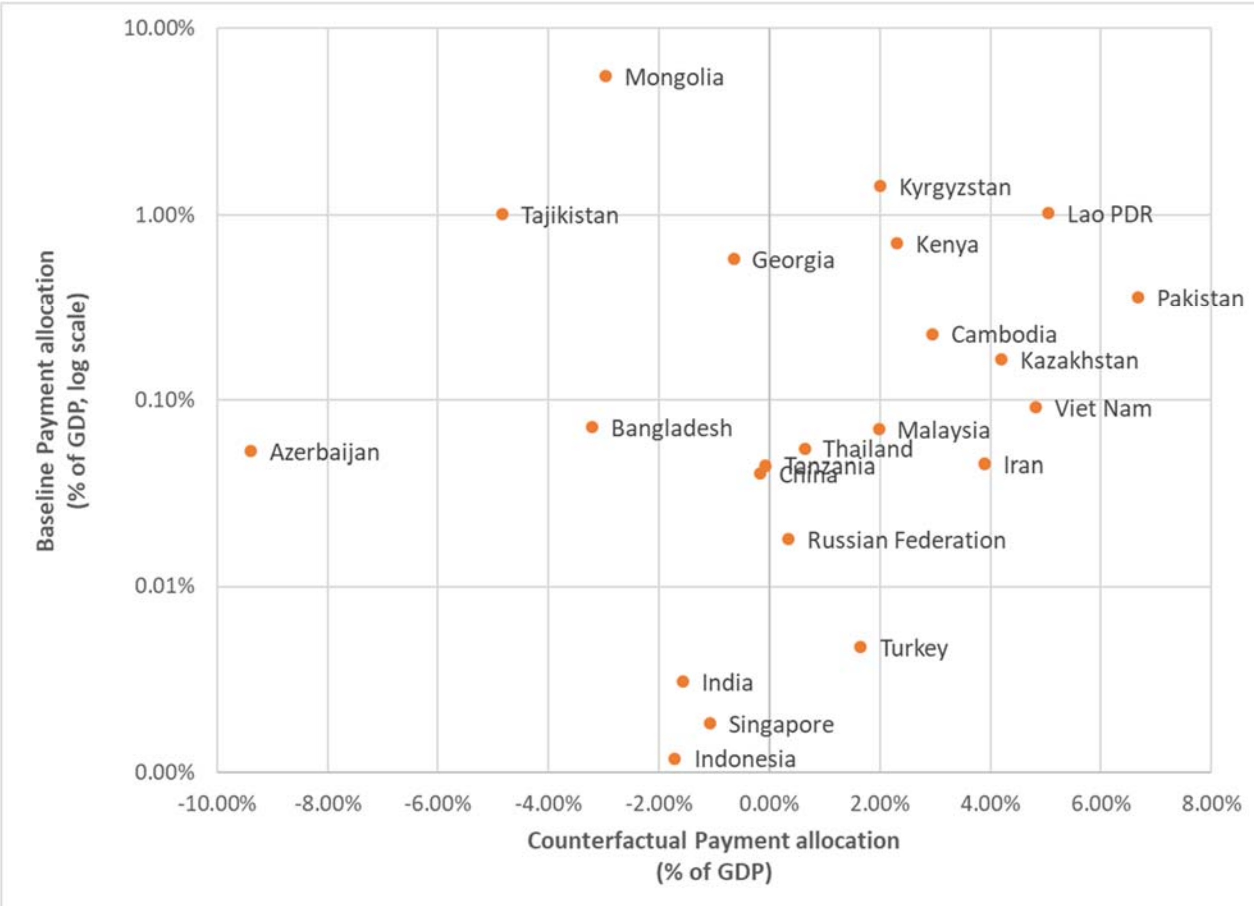


e. Counterfactual payment allocation

Results presented in the previous section highlight the heterogeneity of gains but also the mis-alignment of gains and costs across countries. This mis-alignment is linked to the systemic nature of a transportation network: the value of a project cannot be determined individually but potentially depends on all other projects implemented around the world as well as the current state of the network. Moreover, by creating complex interdependence in production costs, input-output linkages across countries not only magnify the gains, but also impact the distribution of those gains across countries.

To refine this insight, we perform an additional quantitative exercise in which we keep total investment costs unchanged at the estimated value and compute a counterfactual allocation of payments among BRI countries that would equalize the proportional welfare gains. More precisely, keeping the total cost constant and starting with the initial allocation as described in Table 4, we iterate over the share of total payment attributed to each country, reducing the payment share for countries with low welfare gains and increasing payment share for countries with high welfare gains, until all welfare gains are equalized. The final payment allocation features an average welfare gain of 2.8 percent among all BRI countries, which almost exactly the same as the baseline simulations (which featured an average gain of 2.81 percent for BRI countries). Country-specific results of this exercise are presented in Figure 13.

Figure 13: Investment Cost Allocation for Equal Welfare Gains in BRI Countries



Interestingly, our counterfactual payment allocation looks more like a transfer scheme, as some countries end up with a *negative* payment: in order to equalize all welfare gains among BRI members, it is necessary that some countries with large gains in the baseline allocation transfer money to countries with losses. As expected, countries that experience welfare loss in the baseline allocation (Mongolia and Azerbaijan in the upper-bound scenario, with Tajikistan experiencing a loss only in the lower bound scenario) are now compensated for their losses. As an example, Mongolia, which annualized payment was estimated to more than 5 percent of its GDP in the baseline, would benefit from a lump sum transfer of close to 3 percent of its GDP under the counterfactual allocation. In the case of Tajikistan and Azerbaijan, baseline payments are much lower (1.01 percent and less than 0.1 percent respectively) and reducing those payment to zero is far from enough to compensate their low gains. As a result, those countries must receive large transfers in the counterfactual allocation to reach the average welfare gains for all BRI countries.

4. Conclusion

In this paper, we present a framework to study the effects of common transport infrastructure. The model builds on structural general equilibrium models used for trade policy analysis, allowing to consider the effect that transport infrastructure has on trade costs through the reduction in shipping time and on government budget and taxation. This allows to estimate the effects on trade, GDP and welfare (i.e. net of taxation) of common transport infrastructure on participating countries as well as the rest of the world.

We then use this framework to quantify the impact of transport infrastructure related to the Belt and Road Initiative using estimates of the reduction in trade costs as well as of the cost of building the associated transport infrastructure. Results show that gains from the BRI are positive on aggregate but unevenly distributed across countries, with some economies potentially losing from the infrastructure investment. Because the BRI is expected to have a systemic impact on the whole network of transportation links, the rest of the world is expected to gain from the initiative. Finally, our paper emphasizes the strong complementarity between BRI transport infrastructure projects and other policy reforms such as trade facilitation and tariff reduction.

References

1. ADB, UKAID, JICA, and World Bank Group. (2018). The WEB of Transport Corridors in South Asia. Washington, DC: World Bank.
2. Allen, T. and C. Arkolakis (2017). The welfare effects of transportation infrastructure improvements. Working Paper.
3. Bandiera, L. and V. Tsiropoulos (2019). A Framework to Assess Debt Sustainability and Fiscal Risks under the Belt and Road Initiative. *World Bank Policy Research working paper; no. WPS 8891.*
4. Baniya, S., Rocha, N., and Ruta, M. (2019). Trade Effects of the New Silk Road: A Gravity Analysis, *World Bank Policy Research working paper; no. WPS 8694.*
5. Bird, J., Lebrand, M., and Venables A. (2019). The Belt and Road Initiative: Reshaping Economic Geography in Central Asia?. *World Bank Policy Research working paper; no. WPS 8807.*
6. Caliendo, L., and Parro, F. (2015). Estimates of the Trade and Welfare Effects of NAFTA. *Review of Economic Studies* 82, 1, 1–44.
7. Caliendo, L., Dvorkin M. and Parro F. (2018). Trade and Labor Market Dynamics: General Equilibrium Analysis of the China Trade Shock. *Forthcoming: Econometrica*
8. Dekle, R., Eaton, J. and Kortum S. (2008). Global Rebalancing with Gravity: Measuring the Burden of Adjustment, *IMF Staff Papers, 55(3), 511-540.*
9. de Soyres, F., Mulabdic, A., Murray, S., Rocha, N. and Ruta, M. (2019). How Much Will the Belt and Road Initiative Reduce Trade Costs? *International Economics, 159C (2019), pp. 151-164.*
10. Djankov, S., Freund, C., and Pham, C. S. (2010). Trading on Time. *The Review of Economics and Statistics* 92, 1, 166–173.
11. Donaldson, D. (2018). Railroads of the Raj: Estimating the impact of transportation infrastructure. American Economic Review 108(4-5), 899–934.
12. Donaldson, D. and R. Hornbeck, (2016). Railroads and American Economic Growth: a "Market Access" Approach. Quarterly Journal of Economics, 131(2):799-858.
13. Eaton, J., and Kortum (2002). S. Technology, Geography, and Trade. *Econometrica, 70(5)*
14. Fajgelbaum, P. D. and E. Schaal (2017). Optimal transport networks in spatial equilibrium. National Bureau of Economic Research.
15. Hummels, D. (2001). Time as a trade barrier. *Unpublished paper, Purdue University*
16. Hummels, D., P. Minor, M. Reisman, and E. Endean (2007). "Calculating Tariff Equivalents for Time in Trade" Working Paper, Nathan Associates for US Agency for International Development.

17. Hummels, D. L., and Schaur, G. (2013). Time as a Trade Barrier. *American Economic Review* 103, 7, 2935–2959.
18. Lall, S. V. and Lebrand, M. (2019) Who wins, who loses? Understanding the Spatially Differentiated Effects of Belt and Road Initiative. *World Bank Policy Research working paper; no. WPS 8806.*
19. Ollivier, G., Sondhi, J.a; Zhou, N. (2014). High-speed railways in China: a look at construction costs. *China transport topics; no. 9. World Bank Group.*
20. Maliszewska M. and van der Mensbrugghe D. (2019). The Belt and Road Initiative: Economic, Poverty and Environmental Impacts. *World Bank Policy Research working paper; no. WPS 8814.*
21. Santamaria, M. (2018). The Gains from Reshaping Infrastructure: Evidence from the Division of Germany. *Unpublished Working Paper*.
22. Slack, B., Comtois, C., Wiegmans, B., and Witte, P. (2018). Ships time in port. *International Journal of Shipping and Transport Logistics*.
23. Zhai, F. (2018). China's belt and road initiative: A preliminary quantitative assessment. *Journal of Asian Economics, Elsevier, vol. 55(C), pages 84-92*.

ANNEX A – Equilibrium conditions in relative changes

For any variable x, we define the ex-post value as being x' and the relative change as $\hat{x} = x'/x$. Equilibrium conditions in relative changes satisfy the following set of equations:

Cost of inputs

$$\hat{x}_n^j = \left[\hat{r}_n^{\beta_n} \hat{w}_n^{(1-\beta_n)}\right]^{\gamma_n^j} \prod_{k=1}^{J} \left(\hat{P}_n^k\right)^{\gamma_n^{jk}} \tag{A1}$$

Prices

$$\hat{P}_n^j = \left(\sum_{i=1}^{N} \pi_{ni}^j \left(\hat{x}_i^j \hat{\kappa}_{ni}^j\right)^{-\theta^j} \left(\hat{A}_i^j\right)^{\theta^j \gamma_i^j}\right)^{-1/\theta^j} \tag{A2}$$

Trade shares

$$\hat{\pi}_{ni}^j = \left(\frac{\hat{x}_i^j \hat{\kappa}_{ni}^j}{\hat{P}_n^j}\right)^{-\theta^j} \left(\hat{A}_i^j\right)^{\theta^j \gamma_i^j} \tag{A3}$$

Market clearing

$$X_n^{j'} = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} \frac{\pi_{in}^{k'}}{1 + t_{in}^{k'}} X_i^{k'} + \alpha_n^j \frac{I_n'}{1 + \tau_n^{C'}} \tag{A4}$$

Income

$$I_n' = \widehat{w_n L_n} w_n L_n - \tau_n^{L'} + \iota_n \chi' + T_n' \tag{A5}$$

Trade balance

$$\sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{j'}}{1 + t_{ni}^{j'}} X_n^{j'} + \Upsilon_n' = \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{in}^{j'}}{1 + t_{in}^{j'}} X_i^{j'} \tag{A6}$$

where $\Upsilon_n' = r_n' H_n' - \iota_n \chi'$.

ANNEX B – Extra Tables and Figures

Table B1: List of countries

Country/Region Name	GTAP Code	WB Region	WB Income Level	BRI	BRI core
Azerbaijan	AZE	Europe & Central Asia	Upper middle income	1	1
Bangladesh	BGD	South Asia	Lower middle income	1	1
Cambodia	KHM	East Asia & Pacific	Lower middle income	1	1
China	CHN	East Asia & Pacific	Upper middle income	1	1
Georgia	GEO	Europe & Central Asia	Lower middle income	1	1
India	IND	South Asia	Lower middle income	1	1
Indonesia	IDN	East Asia & Pacific	Lower middle income	1	1
Iran, Islamic Rep.	IRN	Middle East & North Africa	Upper middle income	1	1
Kazakhstan	KAZ	Europe & Central Asia	Upper middle income	1	1
Kenya	KEN	Sub-Saharan Africa	Lower middle income	1	1
Kyrgyzstan	KGZ	Europe & Central Asia	Lower middle income	1	1
Lao PDR	LAO	East Asia & Pacific	Lower middle income	1	1
Malaysia	MYS	East Asia & Pacific	Upper middle income	1	1
Mongolia	MNG	East Asia & Pacific	Lower middle income	1	1
Pakistan	PAK	South Asia	Lower middle income	1	1
Russian Federation	RUS	Europe & Central Asia	Upper middle income	1	1
Singapore	SGP	East Asia & Pacific	High income	1	1
Tajikistan	TJK	Europe & Central Asia	Lower middle income	1	1
Tanzania	TZA	Sub-Saharan Africa	Low income	1	1
Thailand	THA	East Asia & Pacific	Upper middle income	1	1
Turkey	TUR	Europe & Central Asia	Upper middle income	1	1
Vietnam	VNM	East Asia & Pacific	Lower middle income	1	1
Albania	ALB	Europe & Central Asia	Upper middle income	1	0
Armenia	ARM	Europe & Central Asia	Lower middle income	1	0
Bahrain	BHR	Middle East & North Africa	High income	1	0
Belarus	BLR	Europe & Central Asia	Upper middle income	1	0
Bulgaria	BGR	Europe & Central Asia	Upper middle income	1	0
Croatia	HRV	Europe & Central Asia	Upper middle income	1	0
Czech Republic	CZE	Europe & Central Asia	High income	1	0
Egypt, Arab Rep.	EGY	Middle East & North Africa	Lower middle income	1	0
Estonia	EST	Europe & Central Asia	High income	1	0
Greece	GRC	Europe & Central Asia	High income	1	0
Hong Kong SAR, China	HKG	East Asia & Pacific	High income	1	0
Hungary	HUN	Europe & Central Asia	High income	1	0
Israel	ISR	Middle East & North Africa	High income	1	0
Jordan	JOR	Middle East & North Africa	Lower middle income	1	0
Kuwait	KWT	Middle East & North Africa	High income	1	0
Latvia	LVA	Europe & Central Asia	High income	1	0
Lithuania	LTU	Europe & Central Asia	High income	1	0

Country/Region Name	GTAP Code	WB Region	WB Income Level	BRI	BRI core
Nepal	NPL	South Asia	Low income	1	0
Oman	OMN	Middle East & North Africa	High income	1	0
Philippines	PHL	East Asia & Pacific	Lower middle income	1	0
Poland	POL	Europe & Central Asia	High income	1	0
Qatar	QAT	Middle East & North Africa	High income	1	0
Rest of Former Soviet Union	XSU	Europe & Central Asia		1	0
Romania	ROM	Europe & Central Asia	Upper middle income	1	0
Saudi Arabia	SAU	Middle East & North Africa	High income	1	0
Slovak Republic	SVK	Europe & Central Asia	High income	1	0
Slovenia	SVN	Europe & Central Asia	High income	1	0
Sri Lanka	LKA	South Asia	Lower middle income	1	0
Taiwan, China	TWN	East Asia & Pacific	High income	1	0
Ukraine	UKR	Europe & Central Asia	Lower middle income	1	0
United Arab Emirates	ARE	Middle East & North Africa	High income	1	0
Argentina	ARG	Latin America & Caribbean	Upper middle income	0	0
Australia	AUS	East Asia & Pacific	High income	0	0
Austria	AUT	Europe & Central Asia	High income	0	0
Belgium	BEL	Europe & Central Asia	High income	0	0
Bolivia	BOL	Latin America & Caribbean	Lower middle income	0	0
Botswana	BWA	Sub-Saharan Africa	Upper middle income	0	0
Brazil	BRA	Latin America & Caribbean	Upper middle income	0	0
Burkina Faso	BFA	Sub-Saharan Africa	Low income	0	0
Cameroon	CMR	Sub-Saharan Africa	Lower middle income	0	0
Canada	CAN	North America	High income	0	0
Chile	CHL	Latin America & Caribbean	High income	0	0
Colombia	COL	Latin America & Caribbean	Upper middle income	0	0
Costa Rica	CRI	Latin America & Caribbean	Upper middle income	0	0
Côte d'Ivoire	CIV	Sub-Saharan Africa	Lower middle income	0	0
Denmark	DNK	Europe & Central Asia	High income	0	0
Finland	FIN	Europe & Central Asia	High income	0	0
France	FRA	Europe & Central Asia	High income	0	0
Germany	DEU	Europe & Central Asia	High income	0	0
Guatemala	GTM	Latin America & Caribbean	Lower middle income	0	0
Guinea	GIN	Sub-Saharan Africa	Low income	0	0
Honduras	HND	Latin America & Caribbean	Lower middle income	0	0
Ireland	IRL	Europe & Central Asia	High income	0	0
Italy	ITA	Europe & Central Asia	High income	0	0
Jamaica	JAM	Latin America & Caribbean	Upper middle income	0	0
Japan	JPN	East Asia & Pacific	High income	0	0
Korea, Rep.	KOR	East Asia & Pacific	High income	0	0
Luxembourg	LUX	Europe & Central Asia	High income	0	0
Madagascar	MDG	Sub-Saharan Africa	Low income	0	0
Mauritius	MUS	Sub-Saharan Africa	Upper middle income	0	0

Country/Region Name	GTAP Code	WB Region	WB Income Level	BRI	BRI core
Mexico	MEX	Latin America & Caribbean	Upper middle income	0	0
Morocco	MAR	Middle East & North Africa	Lower middle income	0	0
Mozambique	MOZ	Sub-Saharan Africa	Low income	0	0
Namibia	NAM	Sub-Saharan Africa	Upper middle income	0	0
Netherlands	NLD	Europe & Central Asia	High income	0	0
New Zealand	NZL	East Asia & Pacific	High income	0	0
Nigeria	NGA	Sub-Saharan Africa	Lower middle income	0	0
Norway	NOR	Europe & Central Asia	High income	0	0
Panama	PAN	Latin America & Caribbean	Upper middle income	0	0
Paraguay	PRY	Latin America & Caribbean	Upper middle income	0	0
Peru	PER	Latin America & Caribbean	Upper middle income	0	0
Portugal	PRT	Europe & Central Asia	High income	0	0
Rest of the World	XTW	Rest of the World		0	0
Rwanda	RWA	Sub-Saharan Africa	Low income	0	0
Senegal	SEN	Sub-Saharan Africa	Low income	0	0
South Africa	ZAF	Sub-Saharan Africa	Upper middle income	0	0
Spain	ESP	Europe & Central Asia	High income	0	0
Sweden	SWE	Europe & Central Asia	High income	0	0
Switzerland	CHE	Europe & Central Asia	High income	0	0
Togo	TGO	Sub-Saharan Africa	Low income	0	0
Tunisia	TUN	Middle East & North Africa	Lower middle income	0	0
Uganda	UGA	Sub-Saharan Africa	Low income	0	0
United Kingdom	GBR	Europe & Central Asia	High income	0	0
United States	USA	North America	High income	0	0
Uruguay	URY	Latin America & Caribbean	High income	0	0

ANNEX C – GDP and Welfare Results by Country

Table C1: GDP Impact by Country

	GDP					
	Upper Bound			Lower Bound		
Country Name	Infrastructure	Infrastructure, borders, and tariffs	Infrastructure and reduced border delays	Infrastructure	Infrastructure, borders, and tariffs	Infrastructure and reduced border delays
Albania	2.50	10.98	9.08	1.83	6.56	4.37
Armenia	1.92	26.94	17.20	1.49	24.17	14.49
Azerbaijan	6.01	21.10	17.07	5.16	18.27	14.22
Bahrain	2.31	27.98	16.89	0.82	13.06	2.87
Bangladesh	1.13	7.80	5.84	0.83	7.23	5.29
Belarus	2.34	16.75	12.49	0.32	11.38	7.26
Bulgaria	2.17	12.63	8.86	1.59	10.47	6.86
Cambodia	7.01	15.82	12.14	6.90	12.79	8.66
China	3.44	11.22	4.86	2.48	9.03	2.97
Croatia	1.01	3.04	2.10	0.67	1.92	0.72
Czech Republic	1.35	6.46	2.59	0.81	5.52	1.50
Egypt, Arab Rep.	1.54	6.95	4.94	0.68	4.36	2.46
Estonia	1.16	11.69	5.35	0.32	7.85	2.65
Georgia	2.04	4.57	3.52	1.79	3.59	2.66
Greece	2.08	6.84	4.86	1.73	5.76	4.18
Hong Kong SAR, China	2.30	22.11	7.92	1.77	20.86	6.79
Hungary	1.35	11.51	2.79	0.59	9.76	0.69
India	2.09	20.56	6.39	0.93	16.36	3.45
Indonesia	1.45	8.01	2.81	0.13	6.27	1.13
Iran, Islamic Rep.	6.18	15.05	13.43	4.01	11.43	9.62
Israel	1.01	7.70	2.76	0.16	6.11	1.36
Jordan	2.18	12.80	7.60	1.32	10.57	6.51
Kazakhstan	6.47	20.70	20.23	2.27	10.94	10.54
Kenya	4.57	9.29	6.76	3.27	7.21	4.74
Kuwait	5.66	15.68	9.24	5.23	13.83	7.41
Kyrgyzstan	9.04	31.66	31.52	4.53	21.91	22.08
Lao PDR	13.19	22.21	21.64	3.31	5.52	5.35
Latvia	3.26	20.53	9.14	0.40	12.64	1.84
Lithuania	4.72	20.01	9.50	1.13	10.96	2.67
Malaysia	4.64	15.49	7.63	4.27	14.75	6.81
Mongolia	5.66	24.67	25.72	4.55	21.16	22.62
Nepal	2.56	28.31	30.30	0.66	24.37	24.71
Oman	3.76	11.22	10.29	1.09	4.45	3.73
Pakistan	6.43	14.06	12.75	2.25	7.57	6.32
Philippines	3.57	26.32	7.29	2.34	23.89	5.51
Poland	2.10	7.91	6.34	1.13	6.31	4.62
Qatar	6.21	17.54	12.67	1.72	6.85	1.99
Rest of Former Soviet Union	7.96	32.48	19.43	6.17	28.98	15.98
Romania	1.85	6.46	6.17	1.32	4.86	4.51
Russian Federation	2.88	10.59	8.95	1.35	6.30	4.71
Saudi Arabia	5.02	13.71	13.03	2.01	6.66	5.94
Singapore	2.23	12.96	2.97	0.43	10.57	0.71
Slovak Republic	3.92	13.38	10.05	2.00	8.00	4.88

GDP						
	Upper Bound			Lower Bound		
Country Name	Infrastructure	Infrastructure, borders, and tariffs	Infrastructure and reduced border delays	Infrastructure	Infrastructure, borders, and tariffs	Infrastructure and reduced border delays
Slovenia	1.70	20.25	7.01	0.97	16.60	4.30
Sri Lanka	1.49	8.46	2.14	0.91	7.44	1.22
Taiwan, China	5.20	13.82	10.54	3.73	10.98	7.90
Tajikistan	4.97	31.94	31.31	3.11	28.13	27.54
Tanzania	3.46	15.37	7.84	2.87	14.56	6.84
Thailand	4.16	12.44	5.84	1.58	8.82	2.52
Turkey	4.52	17.32	7.73	4.11	16.05	6.77
Ukraine	3.19	17.50	11.26	1.52	9.55	3.47
United Arab Emirates	1.59	25.25	9.12	0.33	17.86	2.87
Vietnam	6.52	18.73	8.38	4.67	15.97	5.72
non-BRI East Asia & Pacific	6.88	16.36	15.45	2.94	5.90	5.11
non-BRI Europe & Central Asia	1.26	3.02	2.87	0.55	1.45	1.31
non-BRI Latin America & Caribbean	1.88	4.89	4.76	0.62	2.78	2.61
non-BRI Middle East & North Africa	1.21	3.55	2.78	0.98	3.18	2.51
non-BRI North America	2.29	3.68	3.55	0.88	1.43	1.31
non-BRI Rest of the World	2.09	5.73	5.36	1.12	3.14	2.90
non-BRI Sub-Saharan Africa	1.94	4.02	3.57	1.17	2.83	2.35

Table C2: Welfare Impact by Country

	WELFARE					
	Upper Bound			Lower Bound		
Country Name	Infrastructure	Infrastructure, borders, and tariffs	Infrastructure and reduced border delays	Infrastructure	Infrastructure, borders, and tariffs	Infrastructure and reduced border delays
Albania	2.90	10.06	8.40	1.89	6.01	4.44
Armenia	2.52	20.14	11.33	1.70	17.61	8.61
Azerbaijan	-4.06	1.94	-1.29	-4.13	0.85	-2.33
Bahrain	2.63	16.63	6.96	1.19	12.01	2.97
Bangladesh	1.26	6.53	6.24	0.78	5.51	5.24
Belarus	2.45	11.40	8.13	0.64	8.42	5.23
Bulgaria	2.70	9.44	7.79	1.83	7.49	5.98
Cambodia	4.05	9.42	6.36	3.57	7.99	4.98
China	2.70	9.53	4.23	1.92	7.61	2.49
Croatia	1.49	2.41	2.32	1.00	1.02	1.30
Czech Republic	1.72	3.78	2.45	1.02	2.77	1.75
Egypt, Arab Rep.	1.74	3.80	3.97	0.98	2.02	2.02
Estonia	1.68	5.85	4.19	0.67	4.49	2.63
Georgia	2.19	3.93	3.30	1.59	2.67	2.10
Greece	2.35	2.30	4.06	1.58	1.04	2.31
Hong Kong SAR, China	1.95	18.45	6.65	1.27	16.89	5.27
Hungary	1.72	7.77	2.89	0.85	5.99	1.28
India	2.03	14.53	4.88	1.05	12.56	3.48
Indonesia	1.87	6.59	3.21	0.63	4.70	1.49
Iran, Islamic Rep.	5.34	13.61	12.73	3.72	10.25	8.59
Israel	1.07	5.09	2.27	0.51	3.89	1.11
Jordan	2.26	4.09	5.29	1.31	2.59	1.87
Kazakhstan	4.77	8.96	8.36	2.36	5.34	4.62
Kenya	3.53	6.32	5.55	2.43	4.45	3.67
Kuwait	5.48	11.50	8.82	4.66	9.33	6.00
Kyrgyzstan	2.94	5.17	4.95	0.84	3.61	3.65
Lao PDR	4.73	0.50	0.81	1.61	1.38	1.74
Latvia	2.81	11.43	6.62	0.77	5.09	2.46
Lithuania	1.70	9.58	6.37	1.14	6.35	2.43
Malaysia	3.68	12.14	6.45	3.06	10.78	5.25
Mongolia	-1.95	5.33	2.93	-2.96	3.64	0.93
Nepal	2.50	16.29	15.85	0.66	13.49	14.58
Oman	4.23	11.40	9.23	1.67	6.77	4.45
Pakistan	5.18	10.51	9.85	1.48	5.24	4.64
Philippines	2.98	23.98	6.21	1.97	21.61	4.53
Poland	2.34	6.36	5.89	1.37	4.98	4.81
Qatar	5.00	10.39	7.60	1.02	2.08	1.59
Rest of Former Soviet Union	0.49	14.49	3.71	0.69	14.60	3.26
Romania	2.28	6.37	5.11	1.42	4.73	3.69
Russian Federation	2.97	8.49	7.18	1.48	5.17	3.91
Saudi Arabia	5.22	9.91	9.74	2.22	5.00	4.94
Singapore	2.29	11.64	3.09	0.72	9.37	0.90
Slovak Republic	3.78	10.19	8.68	2.07	5.88	4.42
Slovenia	2.34	16.28	5.98	1.23	13.39	3.98
Sri Lanka	1.23	5.74	1.58	0.56	5.08	0.75
Taiwan, China	4.33	11.21	8.79	3.10	8.85	6.53

	WELFARE					
	Upper Bound			Lower Bound		
Country Name	Infrastructure	Infrastructure, borders, and tariffs	Infrastructure and reduced border delays	Infrastructure	Infrastructure, borders, and tariffs	Infrastructure and reduced border delays
Tajikistan	0.84	12.11	10.93	-0.04	10.96	9.96
Tanzania	2.72	13.09	6.96	2.07	12.03	5.68
Thailand	3.07	9.68	6.16	1.33	7.06	3.59
Turkey	3.59	14.20	7.92	2.73	12.23	6.16
Ukraine	3.36	16.11	11.19	1.66	8.28	3.51
United Arab Emirates	3.37	20.81	7.68	1.32	16.17	4.15
Vietnam	4.86	14.87	7.18	3.30	12.04	4.43
non-BRI East Asia & Pacific	6.32	16.93	14.66	2.66	6.95	4.92
non-BRI Europe & Central Asia	1.82	4.51	3.59	0.89	2.73	1.90
non-BRI Latin America & Caribbean	2.44	6.88	6.11	0.93	3.84	3.04
non-BRI Middle East & North Africa	1.76	5.92	3.68	1.11	4.67	2.62
non-BRI North America	2.55	5.27	4.62	1.08	2.26	1.68
non-BRI Rest of the World	2.96	7.96	6.52	1.54	4.30	3.04
non-BRI Sub-Saharan Africa	2.51	6.19	4.92	1.43	3.92	2.67