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## Trade effects of transportation infrastructure among CAREC countries

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# TRADE EFFECTS OF TRANSPORTATION INFRASTRUCTURE AMONG CAREC COUNTRIES

*Suprabha Baniya and Kiyoshi Taniguchi*

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Suprabha Baniya and Kiyoshi Taniguchi

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## ABSTRACT

This paper investigates the trade effects of transportation infrastructure reforms funded by the Asian Development Bank (ADB) in the Central Asia Regional Economic Cooperation (CAREC) program. To do this, we applied a combination of geographic information systems (GIS), econometric, and computable general equilibrium (CGE) analyses. Using GIS analysis, we compute the reduction in bilateral transport time and potential substitution across transportation modes induced by ADB-funded transportation reforms in the CAREC program. Then, using econometric analyses, we examine the direct impacts of transport time on the extensive and intensive margins of trade. We use the average geographical features of trade partners as the instruments of bilateral transport time to address the endogeneity between trade and infrastructure. Finally, implementing the partial equilibrium impacts of transport time reductions on trade in a firm-heterogeneity CGE model in the Global Trade Analysis Project (GTAP), we investigate the additional endogenous effects of transport time on trade. Combining the estimates of bilateral transport time reductions from the GIS analysis and the estimates of extensive and intensive margins of the trade from the two-part model, we find that the ADB transportation reforms in CAREC countries increase the trade values for existing exporters by 3.31% and trade participation by 1.21% on average. Using the CGE analysis, we find that trade values for CAREC countries increase by 2.04% to 8.72%, on average, due to additional endogenous effects on trade. We also find a positive change in total welfare for CAREC countries.

*Keywords:* CAREC, transportation infrastructure, trade pattern and time sensitivity, CGE analysis, GIS analysis

*JEL codes:* R13, R41, F15

# I. INTRODUCTION

This paper examines the trade effects of transportation infrastructure reforms, in terms of roads and railways, funded by the Asian Development Bank (ADB) in the Central Asia Regional Economic Cooperation (CAREC) region. ADB has advocated the alliance of 11 countries—Afghanistan<sup>1</sup>, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, the People’s Republic of China (PRC), Tajikistan, Turkmenistan, and Uzbekistan—as the CAREC program to strengthen economic development via cooperation, growth, and poverty reduction.<sup>2</sup> This ambitious program aims to integrate CAREC’s major economic centers within the region and to the global markets, particularly Eurasia, by enhancing its transportation infrastructure and lowering trade barriers. This initiative is a series of transportation networks, energy pipelines, information and communication infrastructure projects, industrial parks, and streamlined border crossings, which are proposed along the six economic corridors (Figure 1).

**Figure 1: Central Asia Regional Economic Cooperation Corridors**



Note: This report was prepared based on information available for Afghanistan as of 31 July 2021.

Source: Adapted from ADB. 2020. *CAREC Transport Strategy 2030*. Manila: Asian Development Bank.

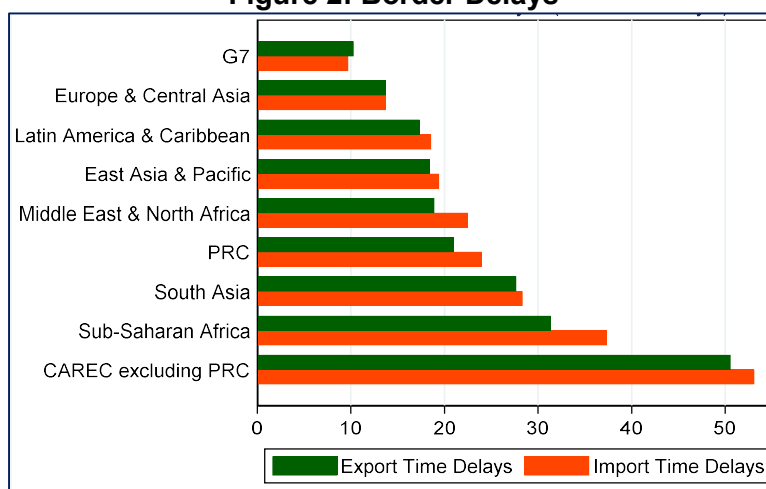
Transportation bottleneck is one of the biggest impediments to trade in landlocked Central Asia. Figures 2 and 3 illustrate that CAREC countries has the largest trade time delays and the second-lowest logistics performance index (LPI), after Sub-Saharan Africa, compared to the rest of the world in 2012 (the base year for this study). Next, Figure 4 demonstrates that countries with a higher quality of transportation infrastructure export relatively more in higher value-added and

<sup>1</sup> ADB placed on hold its assistance in Afghanistan effective 15 August 2021. [ADB Statement on Afghanistan | Asian Development Bank](#) (published on 10 November 2021). Manila.

<sup>2</sup> CAREC program information can be found in CAREC. About CAREC: CAREC Program. [https://www.carecprogram.org/?page\\_id=31](https://www.carecprogram.org/?page_id=31).

processed goods compared to primary commodities. This is because primary goods use relatively less time-sensitive inputs and are integrated less in global production chains compared to processed and higher value-added goods; hence, improvements in transportation infrastructure proliferate trade in processed and higher value-added goods more (Baniya 2017). In fact, Figure 5 shows that countries with a higher quality of transportation infrastructure export relatively more in products that highly use time-sensitive inputs. Thus, the CAREC program will not only facilitate trade for the CAREC countries but will also shift their comparative advantage pattern.

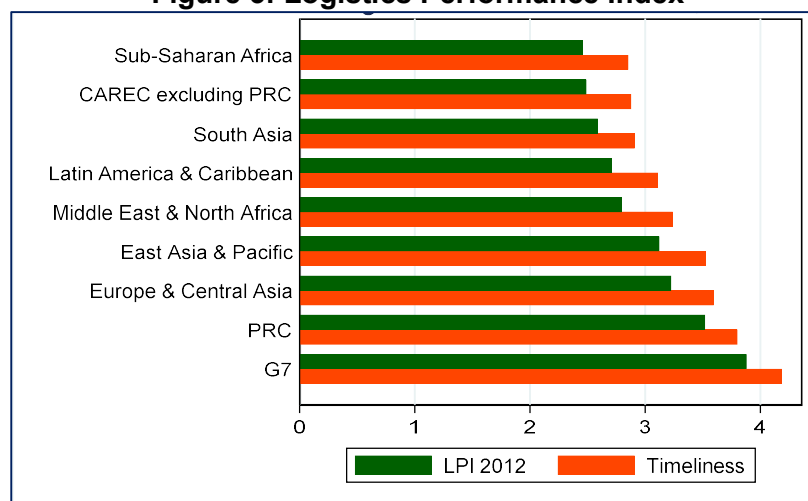
**Figure 2: Border Delays**



CAREC = Central Asia Regional Economic Cooperation Program, G7 = Group of Seven, PRC = People's Republic of China.

Source: World Bank. 2012. *Doing Business*. Washington, DC.

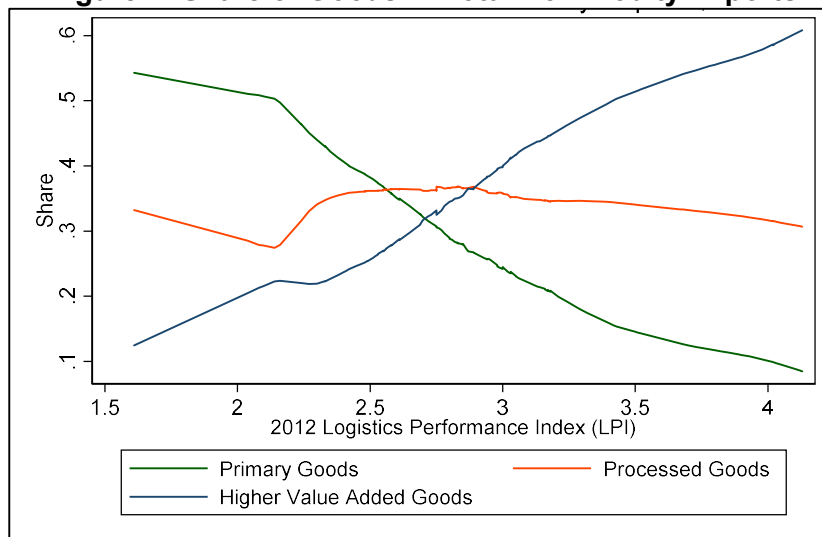
**Figure 3: Logistics Performance Index**



CAREC = Central Asia Regional Economic Cooperation, G7 = Group of Seven, LPI = logistics performance index, PRC = People's Republic of China.

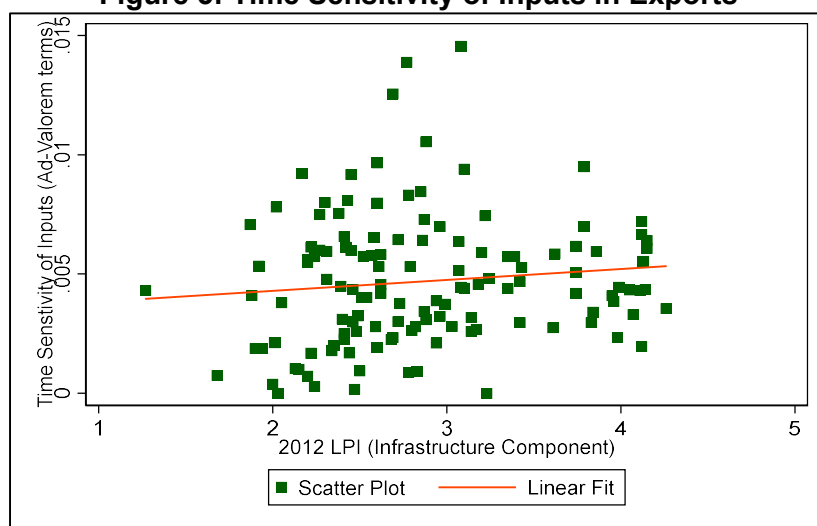
Source: World Bank. The Logistics Performance Index Dataset. <https://lpi.worldbank.org/about> (accessed 25 May 2016).

**Figure 4: Share of Goods in Total Commodity Exports**



Source: Suprabha Baniya. 2017. "Effects of Timeliness on the Trade Pattern between Primary and Processed Goods." IMF Working Paper No. 17/44. International Monetary Fund.

**Figure 5: Time Sensitivity of Inputs in Exports**



LPI = logistics performance index.

Source: Suprabha Baniya. 2017. "Effects of Timeliness on the Trade Pattern between Primary and Processed Goods." IMF Working Paper No. 17/44. International Monetary Fund.

We first assess the changes in bilateral transport time due to ADB-funded transport reforms of roads and railways in CAREC countries following Baniya, Rocha, and Ruta (2020). In doing so, we investigate the potential modal substitution induced by infrastructure reforms. For instance, substantial investment in roadways may provide an incentive to exporters to switch from a slower but cheaper railway to faster but expensive roadway shipping, thereby engendering additional savings in transport time. Next, we explore if those bilateral travel time reductions can result in significant changes in trade flows and determine the trade pattern in time-sensitive products. In



doing so, we must acknowledge that we are analyzing long-distance trade (e.g., the PRC–Europe trade), and therefore, we must examine if transport time reductions are significantly important given the trade partners involved. Also, we must identify the characteristics of the products traded in CAREC countries to fully analyze the trade impacts.

We conduct the geographic information systems (GIS) analysis to compute transport times between capitals and major cities in CAREC countries before and after the ADB-funded transportation reforms. Then we perform an econometric analysis to estimate the effects of bilateral transport time on the extensive and intensive margins of trade for the baseline year, 2012. The extensive margin analysis measures the impact of transport times on the probability of observing a positive trade flow. In contrast, the intensive margin analysis measures the impact of transport time on export values conditional on export participation. Third, we calculate the direct trade impacts of ADB-funded reforms in the CAREC program by combining the GIS estimates of bilateral transport time reductions and the econometric estimates of trade elasticities. Countries that receive the largest infrastructure shocks gain more in terms of trade enhancements. The largest trade benefits stem from transport time reductions for time-sensitive sectors that highly value the timely delivery of their intermediate inputs. Finally, following Baniya and Akgul (2017), we implement the estimated partial equilibrium trade impacts in a firm-heterogeneity computable general equilibrium (CGE) model in the Global Trade Analysis Project (GTAP) to explore additional endogenous effects of transport time reductions on trade through the changes in prices and number of varieties.

We address the potential endogeneity between infrastructure and trade using the average physical geographical features, including terrain ruggedness and the distance to coast, of trade partners as instruments for the bilateral transport time. Additionally, we carry out several robustness tests to identify the effect of transport time on trade. In particular, we use the two-part model to examine the effects of bilateral transport time on export participation and trade values conditional on export participation. Furthermore, we conduct a Poisson pseudo maximum likelihood (PPML) estimation to include zero trade flows in the regression analyses to control for the selection bias. We also include an extensive set of fixed effects to control for any unobserved heterogeneity across country–product and exporter–importer levels. Finally, we control for trade policy, trade agreements, market potential, and gravity variables such as colonial relationships, common language, common legal origin, and contiguity in the estimation.

We find that the ADB-funded transport reforms in CAREC countries decrease the transport time between city pairs by 1.00% to 2.18% on average. This corresponds to an increment in the bilateral trade values for existing exporters by 3.31% and trade participation by 1.21%, on average. There is a sizable variation across country pairs, ranging between 0% to 9.87% increase in trade values for existing exporters and 0% to 3.6% increase in trade participation. In the upper-bound scenario, trade time reductions come from infrastructure reforms as well as additional time-savings from modal substitutions, whereas the lower-bound estimates of travel time reductions are computed by restricting modal substitutions in the network analysis. The lower-bound estimate is that, on average, bilateral trade values increase by 1.16% for existing exporters and trade participation rises by 0.45%, with a significant variation across country pairs, ranging between 0% to 6.7% for the former and between 0% to 2.59% for the latter. We predict the largest improvements in transport time and trade for countries such as Kazakhstan, the Kyrgyz Republic, the PRC, and Tajikistan, and for time-sensitive products. Using a general equilibrium analysis, we find that the trade values (including extensive margins) for CAREC countries increase by 2.04% (lower-bound) to 8.72% (upper-bound), on average, due to additional endogenous effects on trade.

This paper is organized as follows: Section II provides the literature review motivating the methodology in the paper. Section III discusses the network analysis conducted to compute the bilateral transport times before and after the ADB-funded transport reforms in the CAREC program. Section IV discusses the econometric analyses carried out to estimate the direct impacts of bilateral transport time on the extensive and intensive margins of trade and the trade pattern. Section V discusses the CGE analysis conducted to examine the additional endogenous impacts of transport time reductions on trade. Finally, Section VI concludes the paper.

## II. LITERATURE REVIEW

The following works in the literature motivate our study. Banerjee, Duflo, and Qian (2020) investigate the economic effects of access to transportation networks in the PRC. They address the endogenous network placement by claiming that the networks connect historical cities. Martincus, Carballo, and Cusolito (2017) use comprehensive geo-referenced data on firm-level trade to explore trade and employment effects of an asymmetric infrastructure shock in Peru. They use an instrumental variable (IV) estimation method by using the pre-Columbian Inca Road network as an instrument for the present changes in the road network. Alder (2015) studies the effects of a highway project in India that links the four largest economic centers and a counterfactual highway network in India that imitates the Chinese strategy on development. Their identification strategy excludes the nodal points from the network to exploit the exogenous variation in transportation infrastructure in districts that received an unintended shock.

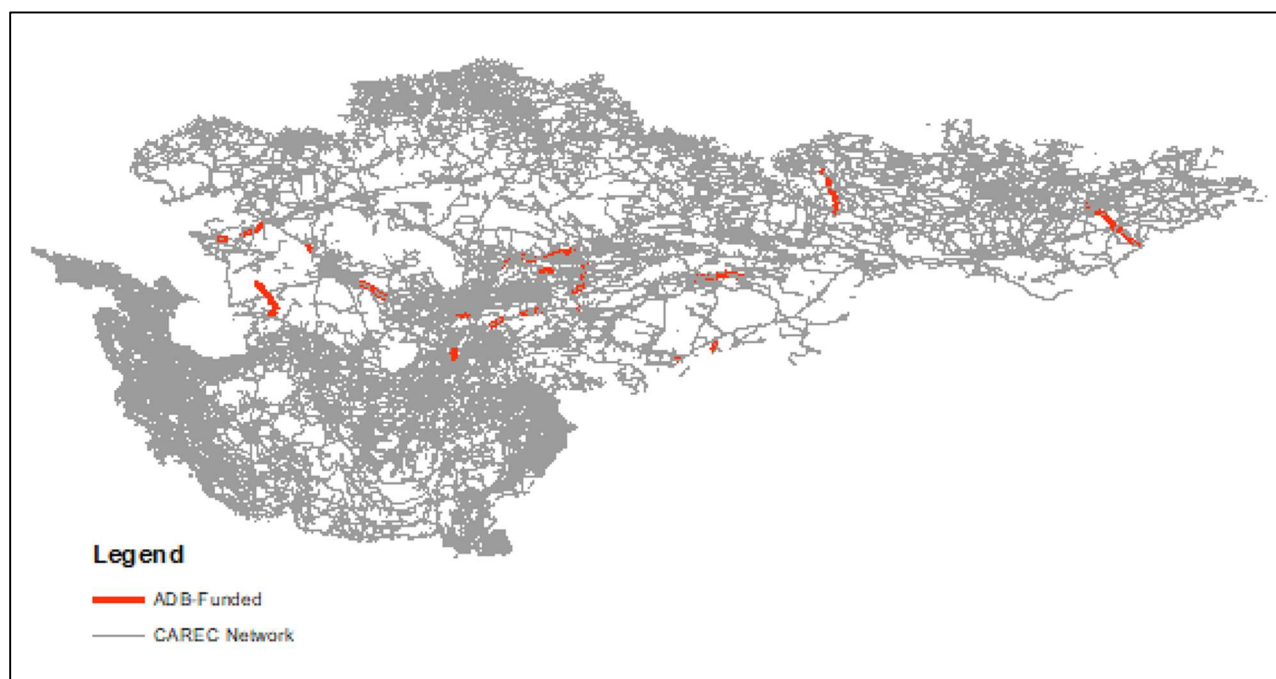
Discussing the effects on the trade pattern, Duranton, Morrow, and Turner (2014) assess the impacts of interstate highways on levels and composition of trade for United States (US) cities, and they find that cities with more highways specialize in heavy goods. They implemented the 1528–1850 exploration routes, 1898 railroads, and the 1947 planned highways as instruments for the modern network of interstate highways. Coşar and Demir (2016) study the effect of a massive public investment in roads in Türkiye on transportation infrastructure quality and the resulting regional access to international markets. They find that transportation-intensive industries have a larger increment in regional exports due to enhanced connectivity to the international gateways of the country. They use the stock of 1945 railroads as instruments of the current changes in the divided road stock within provincial boundaries. Baniya, Rocha, and Ruta (2020) quantify the trade effects of the New Silk Road using a combination of GIS and econometric analyses, and find that products that use time-sensitive inputs, and countries that are highly exposed to the new infrastructure and integrated into global production chains have larger trade gains. They use average physical geography features of transit countries along any trade route as instruments for the bilateral trade time to address the endogeneity between trade and infrastructure.

Following these works, we analyze the trade effects of the ADB-funded transportation reforms in the CAREC program. However, we extend these analyses to investigate the potential extensive margins of trade using a two-part model and additional endogenous effects on trade in a CGE framework. A similar work combining GIS and general equilibrium analyses is conducted in Donaldson (2018), which extracts data from colonial India to explore the impacts of India's railroad network on trade costs and volume, interregional price gaps and income, and addresses the endogenous railroads by estimating the effects of placebo railroad lines. However, our paper differs by examining the general equilibrium trade impacts of transportation reforms using a newly developed firm-heterogeneity CGE model in GTAP (Akgul, Villoria, and Hertel 2016). We examine the potential endogenous effects of transportation reforms on trade arising through changes in prices and the number of varieties.

### III. NETWORK ANALYSIS

The objective of the multimodal transportation network analysis is to quantify the impact of ADB-funded transport reforms, specifically of roads and railways, on transport times between capitals and major cities in CAREC countries. We assess the bilateral transportation times with the transport networks as of 2012 (i.e., before the ADB's transport projects' completion date), and with the new and updated transport networks as of 2017 (i.e., after ADB projects' completion date). Figure 6 shows a detailed map of the ADB-funded road and rail segments in CAREC countries.

**Figure 6: ADB-Funded Reforms in Central Asia Regional Economic Cooperation**



ADB = Asian Development Bank, CAREC = Central Asia Regional Economic Cooperation.

Source: D. Caranay, Suprabha Baniya, A. Hampel-Milagrosa, and K. Taniguchi. 2020. CAREC Multimodal Transport Network Analysis Using GIS. Unpublished mimeo.

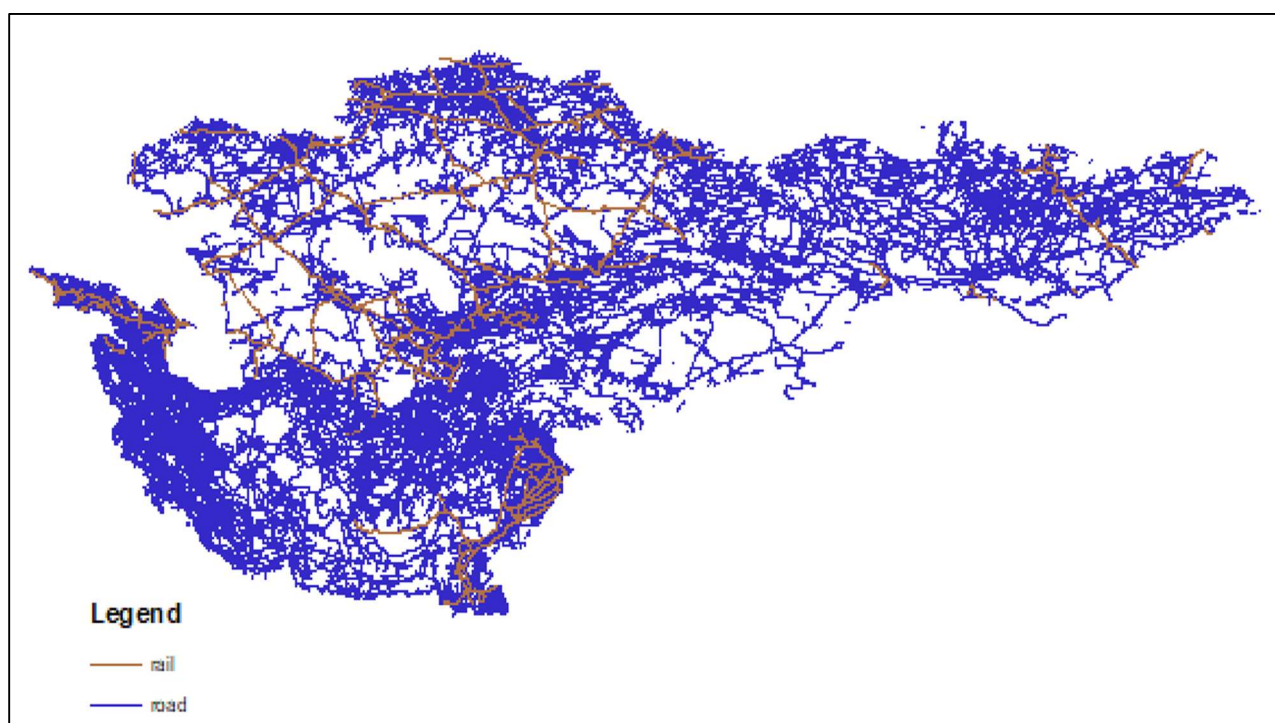
The specifics of this network analysis are available in Caranay et al. (2020), and we provide a summary of the analysis here. Due to the lack of availability of project completion reports (PCRs) and the reports and recommendations to the President (RRPs) for all the projects at ADB, we include 23 out of 34 completed road and rail projects in CAREC countries funded by ADB between 2007 and 2017 in this study. Due to the network data limitations in CAREC countries, we developed a regional database on transport networks by extracting information from the PCRs and RRP, which include significant details on the transport projects (e.g., project cost, completion date, location, travel time, travel cost, and speed limit). These project reports were also beneficial in manually digitizing the ADB-funded completed road segments for the analysis. Moreover, the GIS analysis includes only 74 major cities in CAREC countries due to the complexities of solving the GIS model, and this selection is based on cities' population size.<sup>3</sup>

<sup>3</sup> The details on city selection based on population size are available in Caranay et al. (2020).

## A. Inputs

We extract the primary source of geometry, road and rail networks, from OpenStreetMaps (OSM), 2019 release, and the road and railway shape-files for each country from geofabrik.de.<sup>4</sup> Figure 7 shows the map of rail and road networks in CAREC countries. Next, we manually add the proposed road and railway links from ADB's project reports to this database. Transport network attributes such as speed limit, freight cost, and travel time that are not present in the project reports were introduced later into the database using OSM's built-in data on the speed limit when available. Otherwise, data on default speed limits in each country found on OSM's Wiki page (a repository of OSM's infrastructure) were utilized. Due to the lack of data, information from a third-party database, the AutoDriver Club, were used for Afghanistan, the Kyrgyz Republic, Mongolia, and Pakistan. In addition, we obtain the border delays along the trade routes from the World Bank's Doing Business Survey.

**Figure 7: Rail and Road Network in Central Asia Regional Economic Cooperation**



Source: D. Caranay, Suprabha Baniya, A. Hampel-Milagrosa, and K. Taniguchi. 2020. CAREC Multimodal Transport Network Analysis Using GIS. Unpublished mimeo.

To address potential substitution between transportation modes, as a response to infrastructure shock, we conduct network analysis in multiple scenarios. First, a high preference for cheaper railway mode is enforced in the baseline scenario (transport times as of 2012). In the improved scenario (transport times after 2017), the lower-bound scenario preserves this preference assumption restricting any modal substitution. We relax this preference assumption in the upper-bound scenario to allow for mode switching, whenever possible, to take advantage of faster shipping alternatives. Therefore, travel time reductions in the upper-bound scenario come not

<sup>4</sup> Geofabrik, based in Karlsruhe, Germany, offers OpenStreetMaps consulting, training, tile servers, map styling, and software development services.

only from infrastructure reforms but also from additional travel time-savings derived from modal substitutions. This exercise allows us to incorporate the trade-off between faster travel time associated with roadways and cheaper transportation cost associated with railways.

## B. Network Analysis Results

The network is solved for each origin–destination pair, and the routing is determined by minimum time cost path, where travel time is a function of physical distance traveled and travel speed along each segment of the route, incorporating the preference assumptions. Outputs for each city pair are provided as the distance (in kilometers), travel time (minutes), and the distance by mode. The origin–destination cost matrix that results from this network analysis is 74 cities by 74 cities, i.e., 5,402 city pairs. Transport time between the city pairs is aggregated up to the country pair level using the city populations as weights. Results for both upper-bound and lower-bound scenarios are displayed in Table 1. We find that, on average, transport time falls by 1% to 2.18% among all city pairs. Average transport time reductions for individual countries range between 0.29% to 4.14% (lower-bound) and between 1.00% to 7.44% (upper-bound), as reported in Tables 2 and 3, respectively. The largest reductions in bilateral transport time are predicted for countries such as Kazakhstan, the Kyrgyz Republic, the PRC, and Tajikistan.

**Table 1: Reduction in Bilateral Transport Time in CAREC Countries**

Variable	No. of	Mean	Standard	Minimum	Maximum
	Observation				
	<b>Lower-bound</b>				
	(minute)				
Transport Time (baseline year)	5,041	1,294	733	0	4,614
Transport Time Change (minute)	5,041	-15.08	30.26	-182.49	0
Transport Time Change (%)	4,970	-1.00	1.94	-23.31	0
	<b>Upper-bound</b>				
	(minute)				
Transport Time (baseline year)	4,761	1,312	795	0	4,829
Transport Time Change (minute)	4,761	-32.49	39.04	-199.63	0
Transport Time Change (%)	4,692	-2.18	2.55	-25.93	0

CAREC = Central Asia Regional Economic Cooperation.

Source: Authors' calculations.

**Table 2: Reduction in Bilateral Transport Time by Country, Lower-bound**

<b>Country</b>	<b>Mean Transport Time</b> (minute, base year)	<b>Mean Transport</b> <b>Time Change</b>	<b>Mean Transport</b> <b>Time Change</b> (%)
Kyrgyz Republic	1,385	-49.89	-4.14
People's Republic of China	1,679	-58.19	-3.07
Tajikistan	1,149	-18.91	-1.40
Kazakhstan	1,580	-16.71	-1.27
Georgia	1,355	-14.98	-1.11
Turkmenistan	943	-6.90	-0.52
Uzbekistan	982	-5.37	-0.50
Mongolia	3,121	-13.10	-0.43
Azerbaijan	987	-4.91	-0.36
Pakistan	1,169	-4.95	-0.31
Afghanistan	1,148	-4.22	-0.29

Note: This report was prepared based on information available for Afghanistan as of 31 July 2021.

Source: Authors' calculations.

**Table 3: Reduction in Bilateral Transport Time by Country, Upper-bound**

<b>Country</b>	<b>Mean Transport Time</b> (minute, base year)	<b>Mean Transport</b> <b>Time Change</b>	<b>Mean Transport</b> <b>Time Change</b> (%)
Kyrgyz Republic	1,174	-77.83	-7.44
People's Republic of China	1,568	-68.49	-3.90
Kazakhstan	1,691	-49.34	-3.02
Afghanistan	1,188	-28.07	-2.40
Tajikistan	1,518	-36.33	-2.37
Georgia	1,308	-27.26	-1.99
Uzbekistan	954	-17.44	-1.71
Mongolia	3,287	-59.71	-1.71
Turkmenistan	942	-16.47	-1.34
Pakistan	1,154	-16.60	-1.01
Azerbaijan	990	-13.43	-1.00

Note: This report was prepared based on information available for Afghanistan as of 31 July 2021.

Source: Authors' calculations.

## IV. EMPIRICAL FRAMEWORK

### A. Baseline Equations and the Data Sources

We denote exporters and importers by  $i$  and  $j$ , and products by  $g$ . First, following a gravity analysis similar to Baniya, Rocha, and Ruta (2020), we examine the effects of bilateral transport time on export values in CAREC countries for the baseline year, 2012. To do this, we adopt the following specification:

$$\ln X_{ijg} = \beta_0 + \beta_1 TradeTime_{ij} + Gravity_{ij} + Controls_{ijg} + \lambda_{ig} + \gamma_{jg} + \varepsilon_{ijg} \quad (1)$$

The bilateral export values by exporter–importer and product for the year 2012 ( $X_{ijg}$ ) are extracted from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) database.  $TradeTime_{ij}$  represents the shortest travel time (in minutes) using railways and roadways, as of 2012, computed in Section III.

We control for bilateral gravity variables ( $Gravity_{ij}$ ) obtained from the CEPII database, and they include colonial relationships, common language, common legal origin, contiguity, and regional trade agreements.  $Controls_{ijg}$  represents additional controls for trade policies, market potential, and market access. In particular, for each trade pair, we control for indication and depth of preferential trade agreements obtained from the World Bank's database on the content of Preferential Trade Agreements (Hofmann, Osnago, and Ruta 2017), and importers' market size obtained from Baniya, Rocha, and Ruta (2020). For each exporter–importer–product triplet, we also control for preferential and most favored nation tariff measures extracted from the World Bank's database (Espitia et al. 2018).

Next, we investigate how an ability to transport goods on time determines the comparative advantage in products that are time-sensitive and that value timely delivery of inputs. Following the comparative advantage model similar to Baniya, Rocha, and Ruta (2020), we implement an empirical specification that explains export values by the interactions of exporter–importer specific characteristic with a product-specific characteristic. In particular,

$$\ln X_{ijg} = \beta_0 + \beta_1 TradeTime_{ij} \times t_g + \beta_2 TradeTime_{ij} \times \tilde{t}_g + Controls_{ijg} + \rho_{ij} + \lambda_{ig} + \gamma_{jg} + \varepsilon_{ijg} \quad (2)$$

Direct time-sensitivity by 4-digit Harmonized System classification is expressed in ad-valorem terms ( $t_g$ ), and the data come from Hummels and Schaur (2013). It measures the premium that consumers or end users are willing to pay for a good to be delivered a day earlier. The indirect time-sensitivity across products ( $\tilde{t}_g$ ) is computed in Baniya (2017) using the direct time-sensitivity of products and the input usage drawn from the US input-output tables. It measures the time-sensitivity of the bundle of intermediate inputs used in products.

In both specifications, we include an extensive set of fixed effects: exporter–product and importer–product specific fixed effects. They control for any effect on trade due to country–product specific characteristics: (i) sources of comparative advantage, (ii) agglomeration forces or co-location effects, and (iii) market potential and trade intensity. Equation 2 includes the exporter–importer level fixed effects to control for any confounding factors at the bilateral level, including the gravity variables in Equation 1.

## B. Empirical Framework Interpretation

Equation 1 provides the trade elasticities with respect to transport time ( $\beta_1$ ), as reported in Table 4. We report the results using both the lower-bound and upper-bound estimates of the bilateral transport time. The coefficient of interest is negative and significant across all specifications and robustness tests. Hence, a reduction in transport time by one unit leads to a growth in trade values by  $100 \times \beta_1$  percent in absolute values. Combining the baseline (OLS) estimates of  $\beta_1$  and the average changes in bilateral transport time obtained from the GIS analysis, we find that ADB-funded transport reforms increase the trade values by 1.3% to 3.41%, on average, among trading partners.

Equation 2 provides the effects of transport time on the trade pattern:  $\beta_1 \times t_g + \beta_2 \times \tilde{t}_g$ , where  $\beta_1 \times t_g$  signifies the direct effects of infrastructure reforms, while  $\beta_2 \times \tilde{t}_g$  represents the indirect effects of infrastructure reforms arising through the input–output linkages. The direct effect of reforms is derived from the improvement in the ability to transport the final products to the end-users on time, whereas the indirect effect of reforms comes from the enhancement in the ability to access the intermediate inputs on time. Hence, a one-unit reduction in transport time leads to a growth in the export pattern by  $100(\beta_1 \times t_g + \beta_2 \times \tilde{t}_g)$  percent in absolute values. Table 5 reports that the coefficients of interest ( $\beta_1; \beta_2$ ) are significantly negative across all specifications, indicating that the CAREC countries that can transport goods on time export relatively more in those industries that are time-sensitive and that value timely delivery of their inputs. Combining the baseline (OLS) estimates of  $\beta_1$  and  $\beta_2$ , and average changes in bilateral transport time obtained from the GIS analysis, the ADB-funded transportation reforms increase the trade pattern in time-sensitive goods by 0.49% to 2.04%, on average, among trade partners.



**Table 4: Empirical Framework 1—Baseline Results**

VARIABLES	Lower-bound Scenario				Upper-bound Scenario			
	CAREC–CAREC Trade		CAREC–World Trade		CAREC–CAREC Trade		CAREC–World Trade	
	OLS	PPML	OLS	PPML	OLS	PPML	OLS	PPML
	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)
Transport Time	-0.000733*** (0.000250)	-0.000625*** (5.53e-05)	-0.000610*** (1.95e-05)	-0.000348*** (6.97e-06)	-0.000948*** (0.000273)	-0.000327*** (6.26e-05)	-0.000674*** (2.33e-05)	-0.000423*** (8.33e-06)
Observations	3,122	39,594	111,307	830,652	3,122	39,594	111,307	830,652
R-squared	0.887	0.880	0.783	0.798	0.887	0.878	0.782	0.799

CAREC = Central Asia Regional Economic Cooperation, Ln = natural log, OLS = ordinary least squares, PPML = Poisson pseudo-maximum likelihood.

Notes: Dependent variable is 2012 bilateral exports by products. All regressions control for bilateral gravity variables, exporter–importer-product specific tariff measures, and include exporter–product and importer–product specific fixed effects. Standard errors in parentheses are clustered by exporter–importer pair. \*\*\* = p<0.01.

Source: Authors' calculations.

**Table 5: Empirical Framework 2—Baseline Results**

VARIABLES	Lower-bound Scenario				Upper-bound Scenario			
	CAREC–CAREC Trade		CAREC–World Trade		CAREC–CAREC Trade		CAREC–World Trade	
	OLS	PPML	OLS	PPML	OLS	PPML	OLS	PPML
	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)	Ln(Exports)
Transport Time × Direct	-0.0242** (0.0114)	-0.0383*** (0.00397)	-0.0134*** (0.00354)	-0.00887*** (0.000926)	-0.0440*** (0.0166)	-0.0566*** (0.00639)	-0.0148*** (0.00400)	-0.0107*** (0.00119)
Transport Time × Indirect	-0.0238** (0.0104)	-0.0364*** (0.00474)	-0.0354*** (0.00273)	-0.0121*** (0.000718)	-0.0508** (0.0208)	-0.0676*** (0.00923)	-0.0408*** (0.00320)	-0.0153*** (0.000890)
Observations	3,775	52,479	120,813	954,760	3,775	52,477	120,813	954,760
R-squared	0.837	0.787	0.740	0.767	0.841	0.791	0.739	0.767

CAREC = Central Asia Regional Economic Cooperation, Ln = natural log, OLS = ordinary least squares, PPML = Poisson pseudo-maximum likelihood.

Notes: Dependent variable is 2012 bilateral exports by products. All regressions control for exporter–importer–product specific tariff measures and include exporter–product, importer–product and exporter–importer specific fixed effects. Standard errors in parentheses are clustered by exporter–importer pair. \*\*\* = p<0.01, \*\* = p<0.05.

Source: Authors' calculations.

### C. Robustness Checks

We next present the baseline results by extending our dataset to CAREC's trading partners worldwide in addition to conducting our analysis limited to trade partners within CAREC only. As the data on bilateral trading times between CAREC and non-CAREC countries are not estimated in Caranay et al. (2020), an extension to this dataset is achieved by utilizing the predictive mean matching technique, where the bilateral trading times between CAREC and non-CAREC countries are predicted using our dataset based on the bilateral geographic characteristics. In particular, these characteristics include the bilateral physical distance, the geographical time difference between the trading partners and the bilateral trading time for the baseline year (2012) estimated in Baniya, Rocha, and Ruta (2020) using a multimodal transport network analysis for the Belt and Road Initiative (BRI) region. The results with this extension to non-CAREC trading partners are reported in both Tables 4 and 5 along with the earlier baseline results limited to CAREC–CAREC trade. We find that the trade elasticity with respect to transportation time is consistently larger for CAREC–CAREC trade compared to that for CAREC–world trade. This is consistent with the literature as the improvements in transportation infrastructure tend to have larger trade effects on countries with lower pre-existing levels and quality of transportation infrastructure.

We next control for zero trade flows in our database to address the selection bias using the Poisson pseudo maximum likelihood (PPML) estimation. The PPML estimates for both empirical frameworks are reported along with the baseline results in Tables 4 and 5. Our PPML estimates are mostly smaller in magnitude compared to the OLS estimates. Therefore, without the control for the selection bias, our OLS estimates are slightly upward biased.

### D. Endogeneity

A fundamental problem that the literature accentuates is the reverse causality between trade and infrastructure. The improvement in transportation infrastructure enhances exports, however, trade partners that have rising trade prospects or that aim to improve their current trade levels will also engage more in trade facilitating efforts. Trade incentives of infrastructure reforms are evident in the case of any multilateral organization-funded large-scale infrastructure investments. These incentives may include: (i) emerging trade prospects of CAREC countries within the region and across global markets; (ii) the PRC's over-capacity in heavy manufacturing industries, which entail access to larger European markets, and the intention to secure energy supplies from resource-rich CAREC countries; and (iii) transportation infrastructure being the biggest hindrance for regional integration in CAREC and Eurasia overall. We primarily use IV estimation to address the reverse causality issue. Below, we provide the IV estimation equations:

First Stage:

$$TradeTime_{ij} = \alpha_0 + \alpha_1 rugged_{ij} + \alpha_2 dist\_coast_{ij} + Gravity_{ij} + Controls_{ijg} + \lambda_{ig} + \gamma_{jg} + \varepsilon_{ijg} \quad (5)$$

Second Stage:

$$\ln X_{ijg} = \beta_0 + \beta_1 \widehat{TradeTime}_{ij} + Gravity_{ij} + Controls_{ijg} + \lambda_{ig} + \gamma_{jg} + \varepsilon_{ijg} \quad (6)$$

$X_{ijg}$  is the bilateral export value by exporter-importer and product for the year 2012.  $TradeTime_{ij}$  represents the shortest travel time (in minutes) using railway and roadways, as of 2012, computed in Section III. All other variables are as described in Section IV.A. We use the average physical geography features of trade partners as the instruments for the bilateral transportation times. To do this, for each country, we extract the data on the percentage of moderately to highly rugged land area ( $rugged_{ij}$ ) and the average distance to the nearest ice-free coast ( $dist\_coast_{ij}$ ) from

Nunn and Puga (2009). These are valid instruments, because, first, the geographical features are exogenous to trade since countries are naturally endowed with the geographical features. Second, geographical features may affect country-specific production patterns and trade, through weather and climate conditions. However, the geographical features have no direct effect on trade conditional on country-product specific characteristics; hence, they are excludable in our estimation that includes exporter–product and importer–product fixed effects. Finally, the geographical features affect the ability of trade partners to transport goods on time, because trade routes that are highly rugged tend to have a lower quality of land transportation, while trade routes that are closer to the coast tend to have well established ports and infrastructure. Hence, trade routes that are highly rugged and are far from the coast have larger transportation times. This intuition is confirmed by our first stage results of the IV estimation method in Table 6.

The results for the first and second stages of the 2SLS estimation using these instruments are presented in Table 6. We find that without controlling for the reverse causality, we slightly overestimate the trade effects of transport time. That is, our OLS estimates are slightly upward biased without the control for the endogeneity between trade and infrastructure. Combining the IV estimates of  $\beta_1$  and the average changes in the bilateral transport time obtained from the GIS analysis, the ADB-funded transportation reforms increase the trade values by 1.05% to 2.37%, on average, among trading partners.

### E. Extensive and Intensive Margin Analysis

Finally, following Francois and Manchin (2007), and Chai and Bailey (2008), we report the regression results using the two-part model (TPM) estimation in order to analyze both the extensive and intensive margins of trade. The first stage of the TPM estimates the effect of transportation time on the probability of observing a positive trade flow. The second stage of the TPM estimates the effect of transportation times on trade flows conditional on trade participation. The TPM estimation equations are as follows:

$$E[\ln X_{ijg}, \mathbf{x}] = \Pr(\ln X_{ijg} > 0, \mathbf{x}) \times E[\ln X_{ijg} | \ln X_{ijg} > 0, \mathbf{x}], \quad (7)$$

where:

$$\Pr(\ln X_{ijg} > 0, \mathbf{x}) = \alpha_0 + \alpha_1 TradeTime_{ij} + Gravity_{ij} + Controls_{ijg} + \lambda_{ig} + \gamma_{jg} + \varepsilon_{ijg} \quad (8)$$

$$E[\ln X_{ijg} | \ln X_{ijg} > 0, \mathbf{x}] = \beta_0 + \beta_1 TradeTime_{ij} + Gravity_{ij} + Controls_{ijg} + \lambda_{ig} + \gamma_{jg} + \varepsilon_{ijg} \quad (9)$$

$X_{ijg}$  is the bilateral export values by exporter-importer and product for the year 2012.  $TradeTime_{ij}$  represents the shortest travel time (in minutes) using railways and roadways, as of 2012, computed in Section III. All other variables are as described in Section IV.A. The results for the first and second stage of the TPM are presented in Table 7. We find that without controlling for trade participation, we slightly overestimate the trade effects of the improvement in transport time for the existing exporters. That is, our OLS estimates are slightly upward biased without controlling for selection. Based on our TPM estimates, the ADB-funded transportation reforms increase the trade participation by 0.45% to 1.21% and trade values for existing exporters by 1.16% to 3.31%, on average, among trading partners (Table 8).

**Table 6: Instrumental Variable Method Results**

VARIABLES	Lower-bound Scenario				Upper-bound Scenario			
	CAREC–CAREC Trade		CAREC–World Trade		CAREC–CAREC Trade		CAREC–World Trade	
	1st Stage Transport Time	2nd Stage Ln(Exports)	1st Stage Transport Time	2nd Stage Ln(Exports)	1st Stage Transport Time	2nd Stage Ln(Exports)	1st Stage Transport Time	2nd Stage Ln(Exports)
Transport Time		-0.000591** (0.000296)		-0.000522*** (9.99e-05)		-0.000658* (0.000349)		-0.000642*** (0.000104)
Ruggedness	1.307e+08*** (2.320e+07)		6.529e+07*** (2.320e+06)		1.549e+08*** (1.938e+07)		5.176e+07*** (1.997e+06)	
Distance to Coast	7.113e+08* (4.130e+08)		1.230e+09*** (7.819e+07)		1.521e+09*** (3.284e+08)		1.527e+09*** (6.825e+07)	
Observations	3,122	3,122	111,307	111,307	3,122	3,122	111,307	111,307
R-squared	0.961	0.887	0.833	0.783	0.972	0.887	0.833	0.782

CAREC = Central Asia Regional Economic Cooperation, Ln = natural log.

Notes: Dependent variable is 2012 bilateral exports by products in the second stage regressions. For the first stage regressions, dependent variable is the bilateral transportation time computed using GIS analysis. All regressions control for bilateral gravity variables, exporter-importer-product specific tariff measures, and include exporter-product and importer-product specific fixed effects. Standard errors in parentheses are clustered by exporter-importer pair.

\*\*\* =  $p < 0.01$ , \*\* =  $p < 0.05$ , \* =  $p < 0.1$ .

Source: Authors' calculations.

**Table 7: Two-Part Model Estimation Results**

VARIABLES	Lower-bound Scenario				Upper-bound Scenario			
	CAREC–CAREC Trade		CAREC–World Trade		CAREC–CAREC Trade		CAREC–World Trade	
	Extensive Margin Pr(Exports>0)	Intensive Margin Ln(Exports)	Extensive Margin Pr(Exports>0)	Intensive Margin Ln(Exports)	Extensive Margin Pr(Exports>0)	Intensive Margin Ln(Exports)	Extensive Margin Pr(Exports>0)	Intensive Margin Ln(Exports)
Transport Time	-0.000255*** (2.98e-05)	-0.000658*** (0.000143)	-0.000325*** (4.82e-06)	-0.000476*** (1.52e-05)	-0.000336*** (3.64e-05)	-0.000921*** (0.000165)	-0.000384*** (5.77e-06)	-0.000530*** (1.82e-05)
Observations	129,192	129,192	2,173,634	2,173,634	129,192	129,192	2,173,634	2,173,634

CAREC = Central Asia Regional Economic Cooperation. Ln = natural log; Pr = Probability.

Notes: Dependent variable is 2012 bilateral exports by products. All regressions control for bilateral gravity variables, exporter-importer-product specific tariff measures, and include exporter-product and importer-product specific fixed effects. Standard errors in parentheses are clustered by exporter-importer pair.

\*\*\* =  $p < 0.01$ .

Source: Authors' calculations.

**Table 8: Effects on Trade Participation and Trade Values by Trade Partners**

<b>Variable</b>	<b>No. of Observation</b>	<b>Mean</b>	<b>Standard Deviation</b>	<b>Minimum</b>	<b>Maximum</b>
	<b>Lower-bound</b>				
	(minute)				
Trade Participation (% Change)	121	0.45	0.56	0	2.59
Trade Values for existing exporters (% Change)	121	1.16	1.45	0	6.69
	<b>Upper-bound</b>				
	(minute)				
Trade Participation (% Change)	121	1.21	0.97	0	3.60
Trade Values for existing exporters (% Change)	121	3.31	2.66	0	9.87

Source: Authors' calculations.

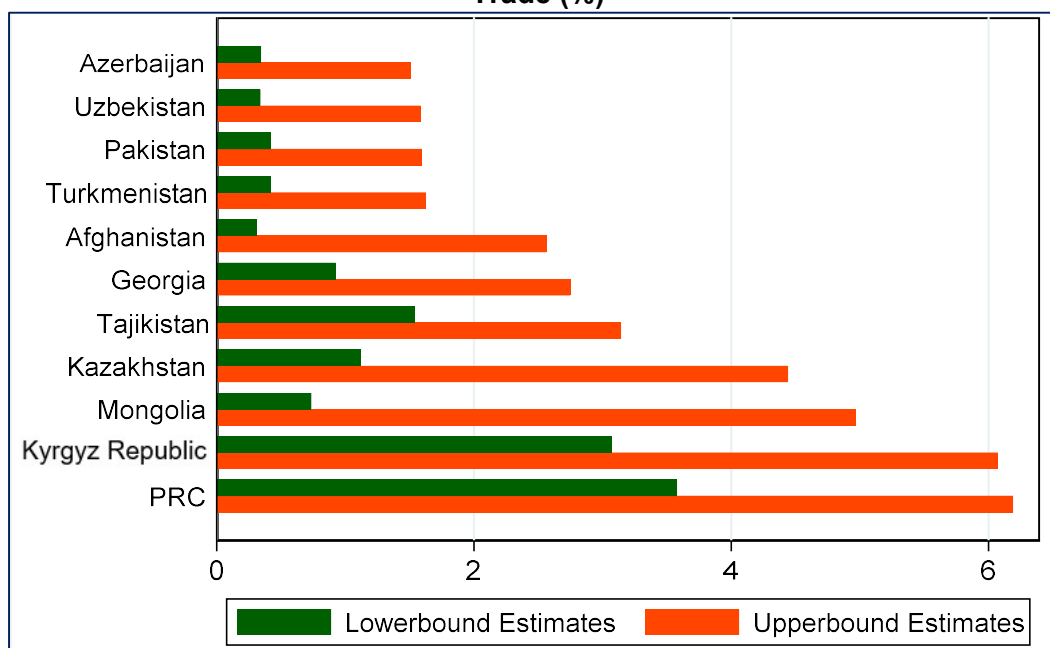
## **F. Partial Equilibrium Impacts**

Combining the estimates of bilateral transport time reductions from the GIS analysis and the estimates of extensive and intensive margins of the trade from the two-part model, we find that the ADB transportation reforms in the CAREC program increase the trade values for existing exporters by 3.31% and trade participation by 1.21% on average (upper-bound estimates in Table 8). In the upper-bound scenario, travel time reductions come from infrastructure improvements as well as additional time savings from modal switching. A lower-bound estimate is that trade increases by 1.16% and trade participation by 0.45% on average (Table 8). In the lower-bound scenario, reductions in travel time come from improvements in infrastructure only.

The changes in bilateral trade values for existing exporters and trade participation considerably vary across country pairs. The upper-bound estimates range between 0% to 9.87% for the former and between 0% to 3.6% for the latter, and the lower-bound estimates range between 0% to 6.7% for the former and between 0% to 2.59% for the latter (Table 8). Figures 8 and 9 show that the largest increment in bilateral trade values for existing exporters and trade participation are predicted for countries such as Kazakhstan, the Kyrgyz Republic, Mongolia, the PRC, and Tajikistan. The biggest gains for countries stem from the degree of exposure to infrastructure shocks and the level of integration in the global production chains.

This can be illustrated through our findings that products that are directly time-sensitive to consumers and end-users, and products that intensively use time-sensitive inputs experience the largest trade gains. Figures 10 and 11 show that time-sensitive sectors that are integrated into the global production chains, such as manufacturing industries, petroleum and coal products, and motor, vehicle, parts and components, experience the largest effect on the trade pattern. This shift in comparative advantage pattern stems not only from the enriched ability to deliver the final products to consumers and end-users on time but also via the improved ability to access intermediate inputs on time. Figures 10 and 11 show that the shift in the trade pattern for these industries may range between 0.18% to 1.52% (lower-bound) and between 0.7% to 5.67% (upper-bound).

**Figure 8: Effects on Bilateral Trade Values for Existing Exporters, Average Change in Trade (%)**

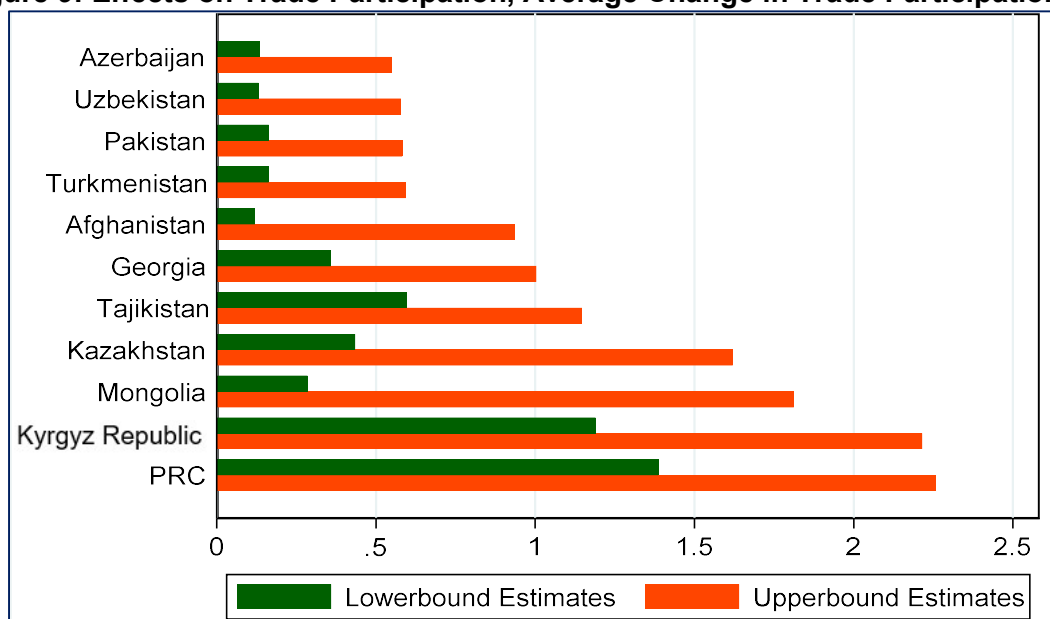


PRC = People's Republic of China.

Note: This report was prepared based on information available for Afghanistan as of 31 July 2021.

Source: Authors' calculations.

**Figure 9: Effects on Trade Participation, Average Change in Trade Participation (%)**

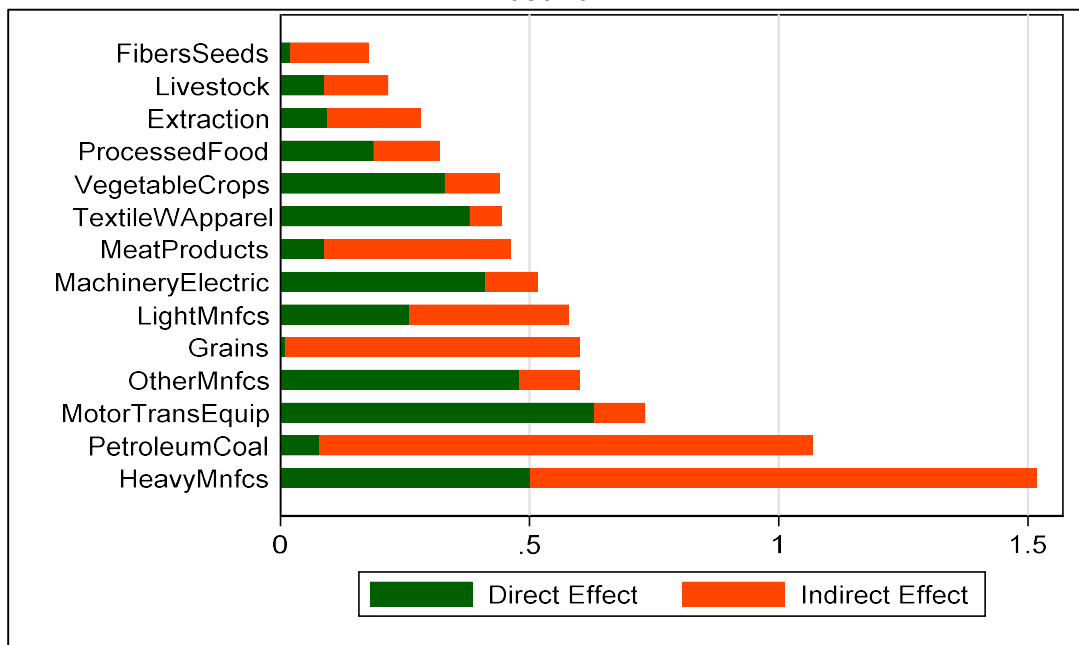


PRC = People's Republic of China.

Note: This report was prepared based on information available for Afghanistan as of 31 July 2021.

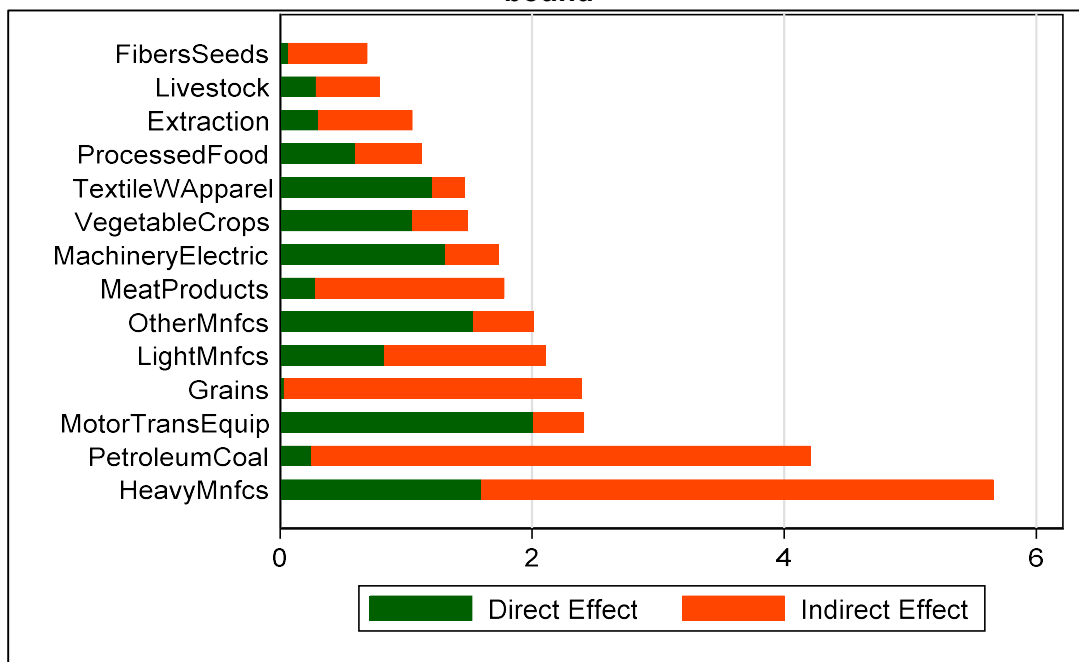
Source: Authors' calculations.

**Figure 10: Effects on Trade Pattern by Industries, Average Change in Trade (%) Lower-bound**



Source: Authors' calculations.

**Figure 11: Effects on Trade Pattern by Industries, Average Change in Trade (%) Upper-bound**



Source: Authors' calculations.



## V. COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

This paper extends the literature on trade and infrastructure by examining the effects of ADB-funded transportation infrastructure in the CAREC program on the extensive and intensive margins of trade using a computable general equilibrium (CGE) analysis. To do this, we use the firm-heterogeneity CGE model in GTAP, which models consumers' love-of-variety, endogenous changes in the number of varieties, and trade-induced productivity changes. Following Baniya and Akgul (2017), we model the improvements in bilateral transport times as efficiency changes in the fixed and variable export costs, which increase the number of firms participating in the export markets and bilateral exports of existing exporters, respectively.

To do this, we exploit the estimates of the extensive and intensive margins of trade obtained from the two-part model. The direct impacts (partial equilibrium [PE] effects) on export costs arise from the improved ability to transport goods on time. Implementing a series of estimated partial equilibrium shocks resulting from enhanced transport times in the CAREC program in the CGE model, we compare the resulting general equilibrium impacts, via changes in prices and number of varieties, across countries and sectors. In addition to fully assessing the trade effects transmitted through regional and sectoral linkages, the CGE analysis explores the welfare and distributional impacts of infrastructure reforms by capturing inter-firm reallocations and the resulting aggregate industry productivity gains.

### A. Global Trade Analysis Project –Firm Heterogeneity Model Summary

A detailed summary of the GTAP–Firm Heterogeneity (HET) model is available in Baniya and Akgul (2017). The GTAP–HET model supposes a multi-region world, where each region comprises two categories of industries. The first assumes perfect competition with identical firms that produce differentiated goods at the national level and with constant returns to scale. We classify primary goods into this category, preserving all characteristics of the standard GTAP model, so that firm prices equal marginal costs. In the second category of industries, monopolistic competition is assumed with a continuum of firms, where each firm produces a unique variety that is an imperfect substitute in demand to others. In this type of industry, a profit-maximizing firm charges a constant markup over marginal costs. We classify processed and higher value-added goods into this category. There are five primary factors of production: land and natural resources are sluggish in primary activities, and unskilled and skilled labor and capital are mobile across sectors.

Following Dixit and Stiglitz (1977), the GTAP–HET models consumer preferences as a CES utility function over differentiated varieties. The import demand function (in a linearized form) for product  $g$  in country  $j$  from country  $i$  is obtained from the consumer utility maximization problem as:

$$q_{ijg} = n_{ijg} + q_{jg} - \sigma_g [\tilde{p}_{ijg} - p_{jg}].$$

Here,  $n_{ijg}$  denotes the variety effect (i.e., consumer demand rises with more number of firms);  $q_{jg}$  represents the expansion effect (i.e., larger market size by destination increases the demand for each exporter), and  $\sigma_g [\tilde{p}_{ijg} - p_{jg}]$  signifies the substitution effect (i.e., demand grows with lower relative prices).

The GTAP–HET integrates this demand system as:

$$\begin{aligned} q_{ijg} &= -ams_{ijg} + n_{ijg} + q_{jg} - \sigma_g [\tilde{p}_{ijg} - ams_{ijg} - p_{jg}]; \\ p_{jg} &= \sum_i \theta_{ijg} (\tilde{p}_{ijg} - ams_{ijg}) - \frac{1}{1-\sigma_g} \sum_i \theta_{ijg} n_{ijg}, \end{aligned}$$

where  $ams_{ijg}$  represents the import augmenting technical change parameter in GTAP as established in Hertel, Walmsley, and Ikatara (2001), and  $\theta_{ijg}$  denotes the expenditure share of good  $g$  from  $i$  in the total expenditure on all varieties from all sources into region  $j$ .

The GTAP–HET model classifies the total costs into variable and fixed components, and the sectors demand labor and capital to cover each type of cost. In the monopolistically competitive industries, firm entry into the domestic market requires covering fixed set-up costs and destination-specific fixed export costs for export markets. That is, the GTAP–HET model characterizes fixed costs as the demand for value-added composite using a Constant Elasticity of Substitution (CES) technology. On the other hand, the model adopts a Leontief production technology, combining demand for variable value-added and intermediate inputs.

The heterogeneous productivity levels across firms in the monopolistically competitive industries are disclosed only upon firm entry. Firms draw their productivity  $\Phi$  from a Pareto distribution with a Cumulative Density Function (denoted as  $G$ ) characterized by a scale parameter  $\Phi_{\min} \in [1, \infty)$ , shape parameter,  $\gamma$ , and the support  $[\Phi_{\min}, \infty)$ . Firms self-select to enter into the export markets only if their productivity levels enable them to secure nonzero profits. That is, the productivity threshold for export market entry (in a linearized form) is obtained from this zero-profit condition as:

$$\varphi_{ijg}^* = c_{jg} - \tilde{p}_{jg} + \frac{1}{\sigma_g - 1} (f_{ijg} - \tilde{q}_{ijg}) + \frac{1}{\sigma_g - 1} (w_{ijg} - \tilde{p}_{ijg} + t_{ijg}).$$

Therefore, the productivity threshold ( $\varphi_{ijg}^*$ ) falls if the market size ( $\tilde{q}_{ijg}$ ) rises, variable costs ( $c_{jg}$ ) relative to product prices ( $\tilde{p}_{jg}$ ) fall, barriers to trade ( $t_{ijg}$ ) and fixed export costs ( $f_{ijg}$ ) fall, value-added composite prices ( $w_{ijg}$ ) relative to product prices ( $\tilde{p}_{ijg}$ ) fall, and  $\sigma_g$  (heterogeneous preferences) falls, which increases the number of firms participating in the export markets.

Next, among the potential entrants that incur the fixed set-up costs to enter industry  $g$  of region  $i$  ( $N_{ig}^p$ ), only a subset of firms ( $N_{ijg}$ ) has a sufficient productivity level to serve the  $ij$  trade route, i.e.  $N_{ig}^p > N_{ijg}$ . Therefore, the probability that a firm participates in the  $ij$  trade route is:

$$G(\Phi_{ijg} > \Phi_{ijg}^*) = 1 - G(\Phi_{ijg}^*) = [\Phi_{ijg}^*]^{-\gamma_g} = \frac{N_{ijg}}{N_{ig}^p}.$$

Linearization gives us:  $n_{ijg} = n_{ig}^p - \gamma_g \varphi_{ijg}^*$ .

Hence, export participation ( $n_{ijg}$ ) rises if the mass of potential firms in the domestic market ( $n_{ig}^p$ ) increases and the productivity threshold for export entry ( $\varphi_{ijg}^*$ ) falls. Moreover, the growth in export participation via a fall in the productivity threshold is magnified by  $\gamma_g$ , as a larger mass of firms is present at the margin in an industry characterized by lower dispersion of firm productivity within an industry (larger  $\gamma_g$ ).

## B. Database and Aggregation

To carry out the CGE analysis, we complement the GTAP–HET model with the GTAP database version 10, which assimilates the production, consumption, and trade data for 141 regions and 65 sectors. Input–output tables by GTAP regions and sectors structure the global and regional input–output linkages, while the international trade and transportation data interlink the GTAP regions and sectors. We aggregate the GTAP regions by singularizing the CAREC countries and by bringing geographically proximate countries together. Note that the GTAP database does not establish an independent input–output database for Afghanistan, and the country is merged with South Asian countries Bhutan and Maldives. Similarly, the GTAP database maintains a joint input–output database for Uzbekistan and Turkmenistan, and therefore, we combine the two countries under one region. We aggregate the GTAP sectors so that sectors with a similar degree of processing and time sensitivity are classified under the same category. In particular, the aggregation consists of 15 regions and 15 sectors (Tables 9 and 10).

**Table 9: Regional Aggregation**

<b>Region</b>	<b>Region Name</b>	<b>Region Description</b>
1	AZE	Azerbaijan
2	PRC	People's Republic of China
3	GEO	Georgia
4	KAZ	Kazakhstan
5	KGZ	Kyrgyz Republic
6	MON	Mongolia
7	PAK	Pakistan
8	TAJ	Tajikistan
9	TKM, UZB	Turkmenistan and Uzbekistan
10	SouthAsia	All South Asia including Afghanistan
11	SEAsia	South East Asia
12	NAmerica	North America
13	EU	European Union
14	MENA	Middle East and North Africa
15	RestofWorld	Rest of the World

Source: Authors' calculations.

**Table 10: Sectoral Aggregation**

<b>Sector</b>	<b>Sector Description</b>	<b>Direct Time Sensitivity</b> (in ad-valorem terms)	<b>Indirect Time Sensitivity</b> (in ad-valorem terms)
1	Grains	0.0001693	0.0107513
2	Fibers seeds	0.0003653	0.0028443
3	Vegetables and crops	0.0057135	0.0019978
4	Livestock	0.0015434	0.0023125
5	Extraction	0.0016553	0.0033948
6	Meat products	0.0015186	0.0068276
7	Processed food	0.0032371	0.0024089
8	Textile and wearing apparel	0.0065767	0.0011673
9	Light manufacturing	0.0044851	0.0058344
10	Petroleum and coal products	0.0013506	0.0180387
11	Other manufacturing	0.0083176	0.0021974
12	Heavy manufacturing	0.0086735	0.018503
13	Machinery and electrical equipment	0.0071182	0.0019291
14	Motor, parts, and transport equipment	0.0109252	0.0018337
15	Services	-	-

Source: Authors' calculations.

### C. Calibration

We calibrate the shocks in the GTAP–HET model, first by imitating the direct impacts (PE effects) of transport time reductions on trade flows for existing exporters through the trade-augmenting technical change variable in GTAP. We achieve this by combining the estimates of transport time reductions computed in Section III and the econometric estimates of intensive margins, controlling for selection, from the TPM in Section IV. This provides the direct effects of transport time reductions on the variable export costs. That is, the direct impact on the import demand comes from the changes in variable export costs. The endogenous effects on trade flows arise through the changes in prices of goods (substitution effects) and the indirect effects on the number of firms (variety effects).

Secondly, we mimic the direct impacts (PE effects) of improvements in transport time on export participation via the efficiency change in fixed trade costs in GTAP. We achieve this by combining the GIS estimates of transport time reductions computed in Section III and the econometric estimates of extensive margins from the TPM in Section IV. That is, the direct impacts of transport time reductions on the number of firms participating in the export markets, and hence, on trade flows, come from the changes in fixed export costs. The endogenous effects on the number of firms come from the changes in prices of value-added composite and the bundle of intermediate inputs that affect fixed export costs, productivity threshold for export entry, and the number of potential entrants in the domestic markets.

To elaborate, we first establish the relationship between export participation,  $\Pr(X_{ijg} > 0)$ , and fixed export cost ( $F_{ijg}$ ). The elasticity of export participation,  $\Pr(X_{ijg} > 0)$ , with respect to fixed export cost from the model is:

$$\frac{\% \Delta \Pr(X_{ijg} > 0)}{\% \Delta F_{ijg}} = - \frac{\gamma_g}{\sigma_g - 1} \quad (10)$$

where  $\sigma_g$  and  $\gamma_g$  are the elasticity of substitution and Pareto shape parameters as in Melitz (2003). These parameters come from Akgul, Villoria, and Hertel (2016), which are then aggregated to the GTAP sectors in the paper.

Next, from the two-part model in Section IV,

$$\frac{\% \Delta \Pr(X_{ijg} > 0)}{\Delta TradeTime_{ij}} = 100 \times \alpha_1 \quad (11)$$

where  $\alpha_1$  is the coefficient estimate of extensive margins from the two-part model (first stage estimation).

$$\text{Thus, combining (10) and (11), } \frac{\% \Delta F_{ijg}}{\Delta TradeTime_{ij}} = -100 \left( \frac{\sigma_g - 1}{\gamma_g} \right) \alpha_1. \quad (12)$$

Therefore, the percentage change in the fixed export costs in sector  $g$  from country  $i$  to  $j$  is  $-100 \left( \frac{\sigma_g - 1}{\gamma_g} \right) \alpha_1$  percent due to a one-unit change in the bilateral transport time, other things being equal. Using this elasticity estimate, we obtain the required amount of shock in the technical change parameter,  $AVAFS_{ijg}$ , that will imitate the direct impacts of the change in bilateral transport times on export participation. That is, for each exporter–importer–product triplet and for a one-unit change in bilateral transport time between countries  $i$  and  $j$ ,

$$(1 - \sigma_g) avafs_{ijg} = \frac{\% \Delta F_{ijg}}{\Delta TradeTime_{ij}} = -100 \left( \frac{\sigma_g - 1}{\gamma_g} \right) \times \alpha_1 \quad (13)$$

To obtain the total amount of shock in  $AVAFS_{ijg}$  required to imitate the direct impact of ADB-funded transport reforms on export participation, we multiply the expression for the technical shock in (13) by the bilateral transport time reductions induced by ADB reforms for each exporter–importer pair computed in Section III.

Secondly, we utilize the coefficient estimate of intensive margins from the TPM in Section IV. Using this trade elasticity with respect to transport times, the change in variable export costs in sector  $g$  from country  $i$  to  $j$  is  $100 \times \beta_1$  percent due to a one-unit change in bilateral transport time. With this information, we obtain the required amount of shock in the technical change parameter,  $AMS_{ijg}$ , that will imitate the direct trade impact of the change in bilateral transport time on the trade flows conditional on trade participation. So, for each exporter–importer–product triplet and for a one-unit change in bilateral transport time,

$$(\sigma_g - 1) ams_{ijg} = \frac{\% \Delta X_{ijg}}{\Delta TradeTime_{ij}} = 100 \times \beta_1 \quad (14)$$

where  $\beta_1$  is the coefficient estimate from the second stage regression of the TPM.

To obtain the total amount of shock in  $AMS_{ijg}$  required to imitate the direct impact of ADB-funded transport reforms on export flows conditional on export participation, we multiply the expression for the technical shock in (14) by the bilateral transport time reductions induced by ADB reforms for each exporter–importer pair computed in Section III. We then implement this series of shocks in  $AMS_{ijg}$  and  $AVAFS_{ijg}$  simultaneously in the CGE analysis assuming a general equilibrium closure to estimate the total general equilibrium effects of ADB-funded transport reforms on trade.

## D. General Equilibrium Impacts

The general equilibrium impact of transport time reductions on trade is a combination of the direct effects of infrastructure reforms (partial equilibrium impacts) and the endogenous effects on trade.

Figure 12 demonstrates that the total trade values—including extensive margins of trade—for CAREC countries increase by 8.72% (upper-bound estimate), on average, after incorporating the endogenous impacts of transport time reductions on trade. In the upper-bound scenario, travel time reductions come from infrastructure improvements as well as additional time-savings from modal switching. A lower-bound estimate (where reductions in travel time come from improvements in infrastructure only) is that total trade values for CAREC countries rise by 2.04% on average. We observe larger impacts of transport time reductions on trade values for countries, including Kazakhstan, the Kyrgyz Republic, and Tajikistan. Figure 13 shows that sectors that use time-sensitive inputs and that are integrated in the global production chains, such as livestock, light manufacturing, processed food, textile and wearing apparel, motor vehicle parts and components, and machinery and electrical equipment and parts, experience the largest trade gains. We estimate that the change in trade values for these industries ranges between 0% to 8.93% (lower-bound) and between 0.51% to 26.04% (upper-bound).

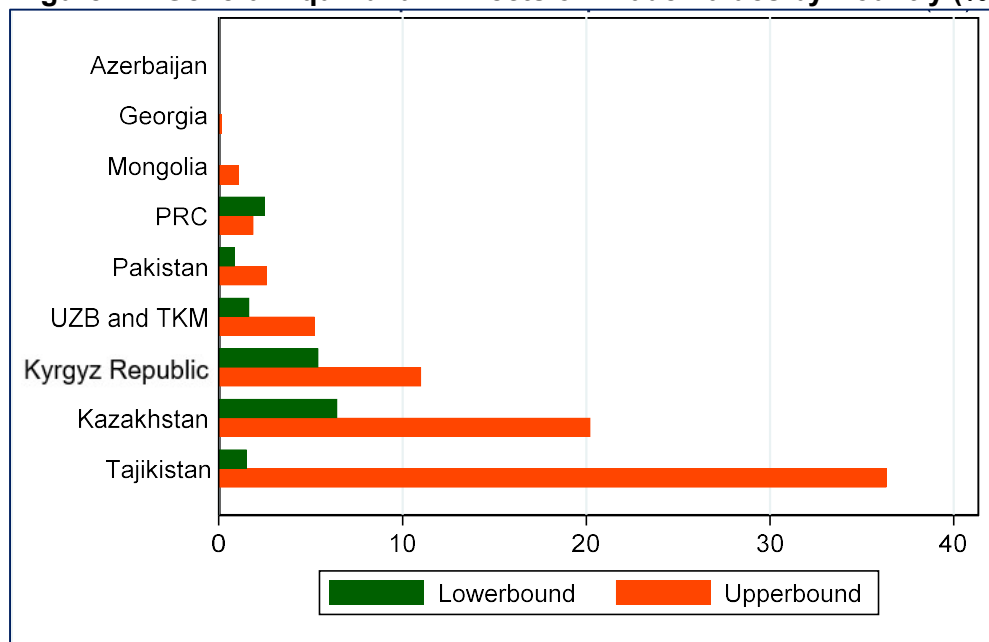
To understand the mechanisms through which the general equilibrium effects arise, we discuss the changes in prices and the number of varieties resulting from transport time reductions. Figure 14 illustrates that transport time reductions in CAREC countries lead to an overall drop in export prices in CAREC countries. This results in positive substitution effects toward CAREC products, which therefore lead to trade expansion for CAREC countries. Product prices fall mainly due to the decline in variable exports costs, which arises directly through transport time reductions and indirectly via a fall in the price of intermediate inputs. Figure 15 confirms that the price of composite intermediate inputs for CAREC countries falls due to transport time reductions.

Another channel through which trade flows increase is the growth in the number of firms participating in the export markets. First, this occurs directly through a reduction in destination-specific fixed export costs due to the transport time reductions. Secondly, export participation rises indirectly through the fall in the productivity threshold for export market entry via a fall in the price of value-added composite and intermediate inputs. Figure 16 confirms that many CAREC countries experience a reduction in the price of value-added in addition to a fall in the price of intermediate inputs, as demonstrated in Figure 15. Additionally, the fall in the prices of value-added lowers the fixed set up costs of production, and therefore, increases the number of potential entrants in the domestic markets. Therefore, relatively less productive firms at the margin are now able to enter export markets.

We now analyze the shift in the comparative advantage pattern toward time-sensitive and higher value-added sectors and sectors that are integrated in the global production chains, as illustrated in Figure 13. In general, transport time reductions shift the trade pattern toward these sectors, leading to a fall in the rental rate of land and natural resources (sluggish factors in primary goods) and a growth in rental rates of labor and capital. **Table 11** Table 11 shows the percentage change in rental rates of primary factors in CAREC countries under the lower-bound scenario, while Table 12 shows the same under the upper-bound scenario. However, we do not find similar results in some resource and extraction-based economies, including Kazakhstan, the Kyrgyz Republic, and Tajikistan. Resource-rich countries would require significantly larger amounts of infrastructure improvements to observe such a shift in their comparative advantage patterns away from

resource intensive products. Figures 17 and 18 demonstrate that the total welfare rises in CAREC countries due to ADB-funded transportation reforms, and most of the welfare gains originate through the direct trade impacts via efficiency changes in export costs.

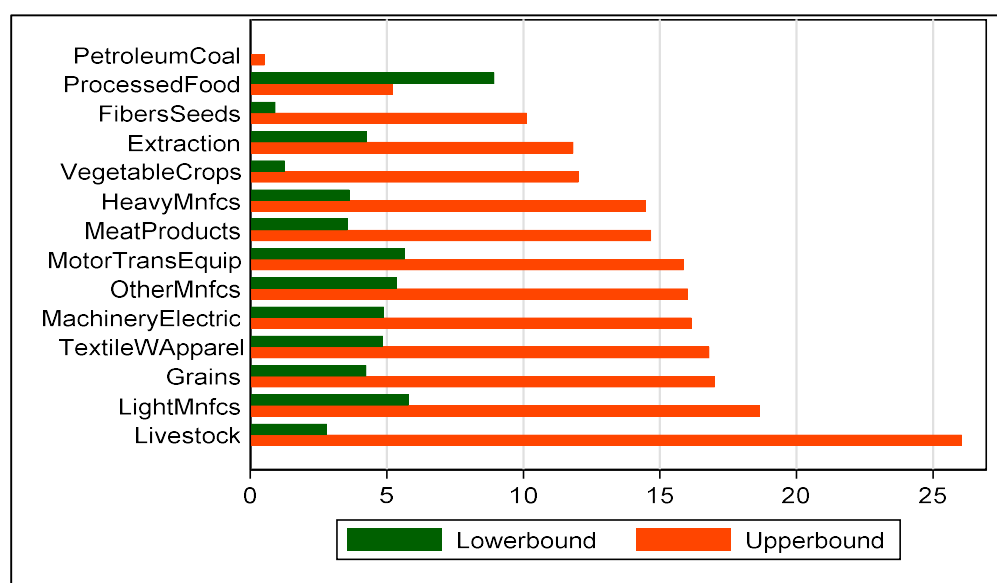
**Figure 12: General Equilibrium Effects on Trade Values by Country (%)**



PRC = People's Republic of China, TKM = Turkmenistan, UZB = Uzbekistan.

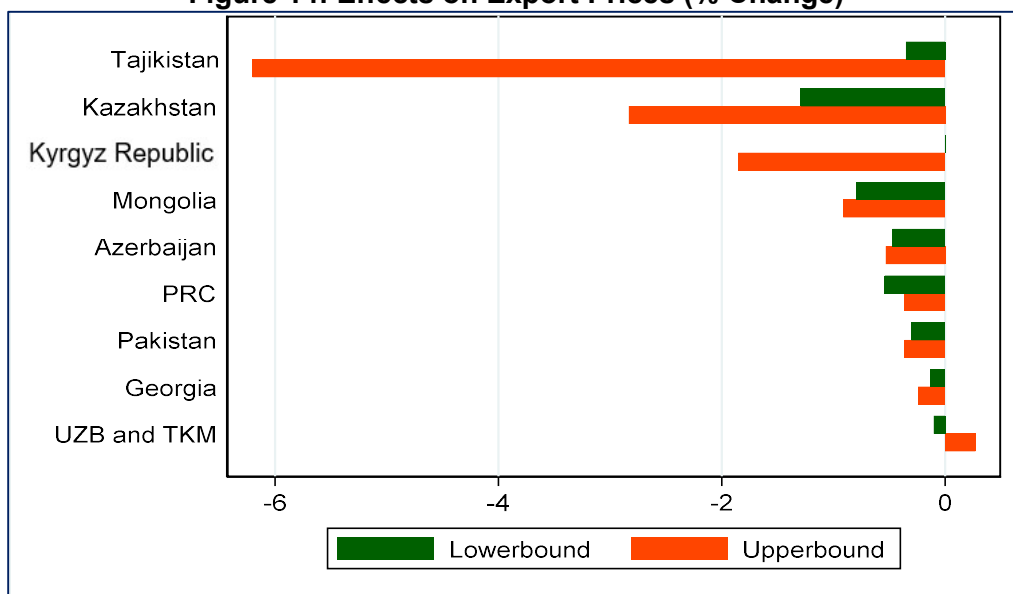
Source: Authors' calculations.

**Figure 13: General Equilibrium Effects on Trade Values by Sector (%)**



Source: Authors' calculations.

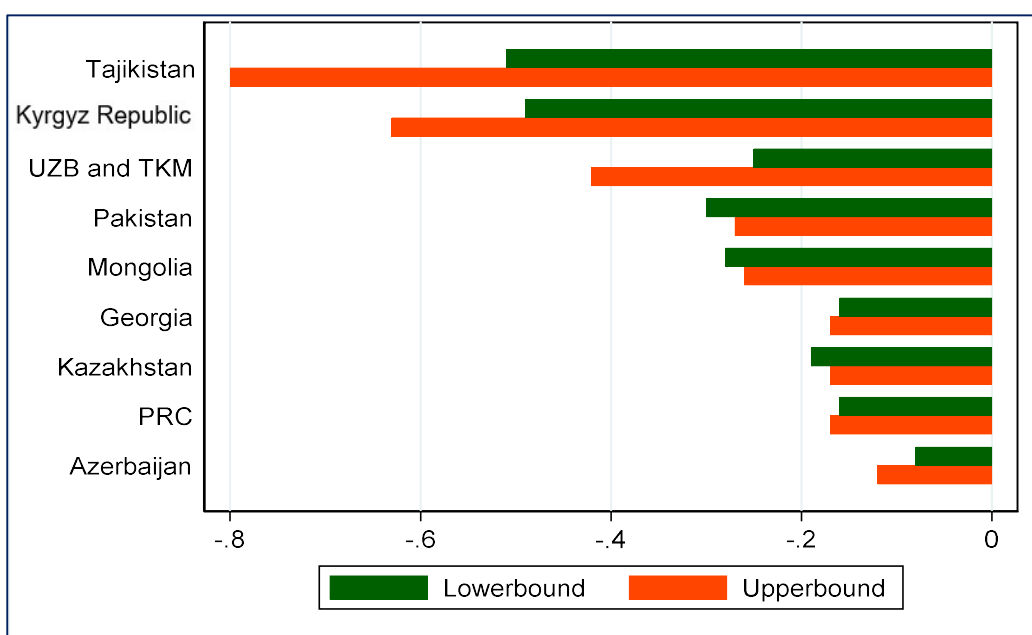
**Figure 14: Effects on Export Prices (% Change)**



PRC = People's Republic of China, TKM = Turkmenistan, UZB = Uzbekistan.

Source: Authors' calculations.

**Figure 15: Effects on Composite Input Prices (% Change)**

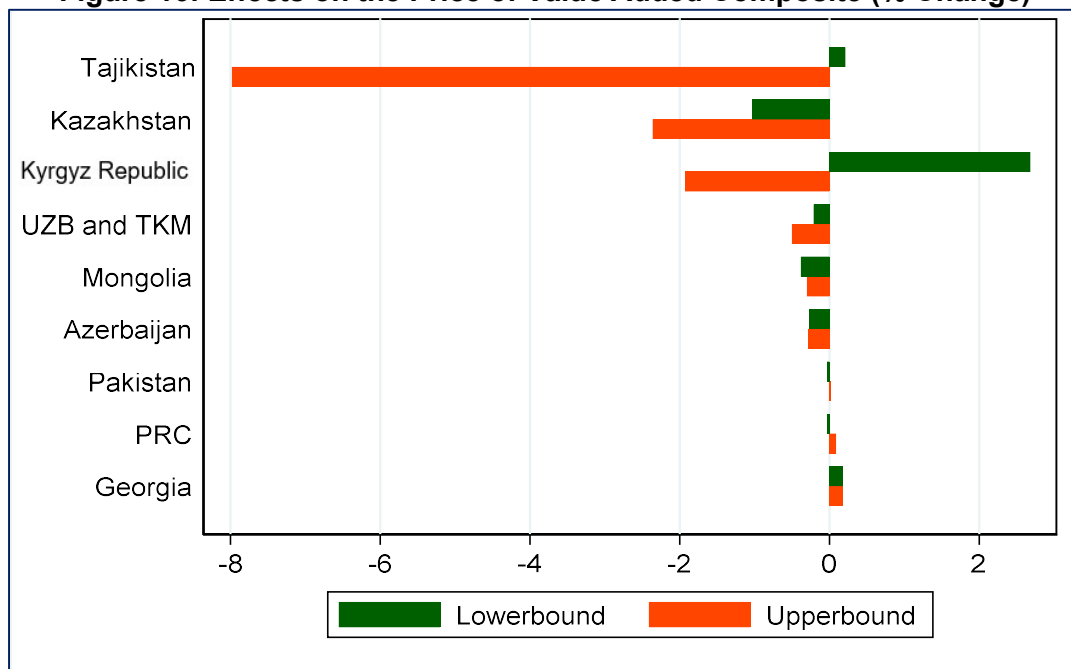


PRC = People's Republic of China, TKM = Turkmenistan, UZB = Uzbekistan.

Source: Authors' calculations.



**Figure 16: Effects on the Price of Value Added Composite (% Change)**



PRC = People's Republic of China, TKM = Turkmenistan, UZB = Uzbekistan.

Source: Authors' calculations.

**Table 11: Effects on the Rental Rates of Primary Factors, Lower-bound**

<b>Primary Factors</b>	<b>AZE</b>	<b>PRC</b>	<b>GEO</b>	<b>KAZ</b>	<b>KGZ</b>	<b>MON</b>	<b>PAK</b>	<b>TAJ</b>	<b>TKM, UZB</b>
<b>Land</b>	0.02	-1.06	-0.38	3.38	1.1	-0.56	-0.27	1.85	-0.95
<b>Unskilled Labor</b>	0.23	0.79	0.59	0.69	4.3	1.08	0.59	1.78	0.4
<b>Skilled Labor</b>	0.16	0.75	0.3	2.06	4.3	0.82	0.34	1.71	0.15
<b>Capital</b>	0.13	0.78	0.51	1.9	4.76	0.7	0.44	0.63	0.3
<b>Natural Resources</b>	-1.28	-3.84	-2.43	7.06	-0.76	0.33	-2.06	12.75	3.83

AZE = Azerbaijan, PRC = People's Republic of China, GEO = Georgia, KAZ = Kazakhstan, KGZ = Kyrgyz Republic, MON = Mongolia, PAK = Pakistan, TAJ = Tajikistan, TKM = Turkmenistan, UZB = Uzbekistan.

Source: Authors' calculations.

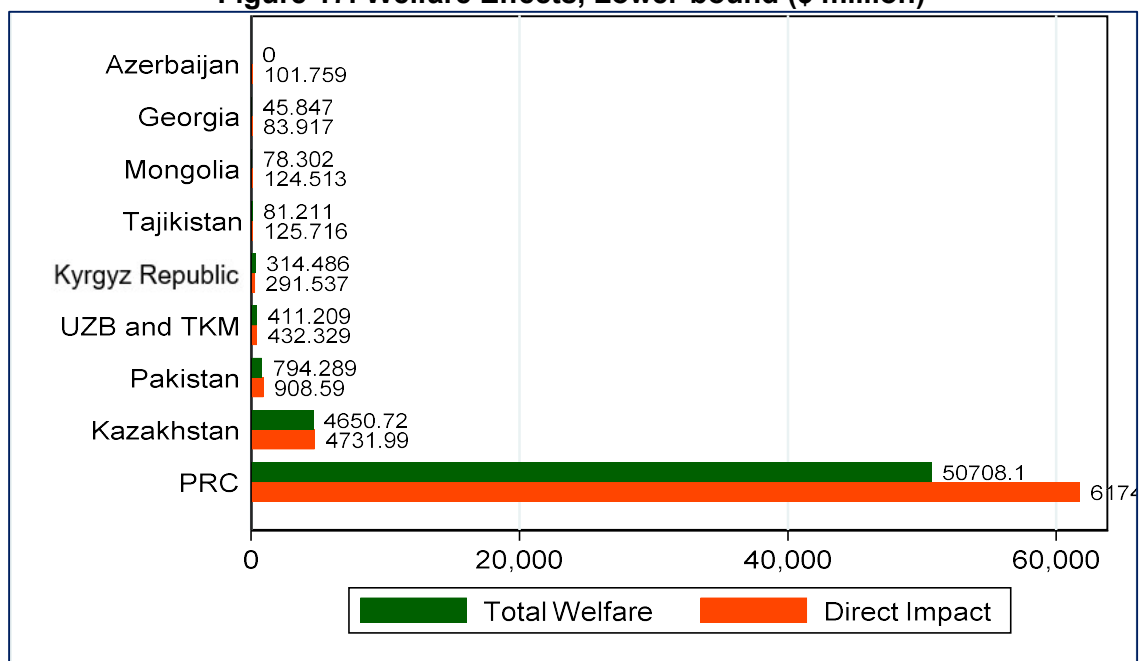
**Table 12: Effects on the Rental Rates of Primary Factors, Upper-bound**

<b>Primary Factors</b>	<b>AZE</b>	<b>PRC</b>	<b>GEO</b>	<b>KAZ</b>	<b>KGZ</b>	<b>MON</b>	<b>PAK</b>	<b>TAJ</b>	<b>TKM, UZB</b>
<b>Land</b>	-0.18	-1	-0.86	7.1	-6.49	-1.94	-0.11	-22.92	-3.41
<b>Unskilled Labor</b>	0.37	0.69	0.88	1.51	1.55	1.92	0.77	4.75	0.46
<b>Skilled Labor</b>	0.26	0.64	0.38	5.7	-0.03	1.38	0.52	0.27	0.05
<b>Capital</b>	0.25	0.68	0.74	5.25	1.59	1.4	0.63	10.74	0.44
<b>Natural Resources</b>	-1.52	-4.31	-0.98	22.39	19.81	4.67	-2.22	78.03	12.61

AZE = Azerbaijan, PRC = People's Republic of China, GEO = Georgia, KAZ = Kazakhstan, KGZ = Kyrgyz Republic, MON = Mongolia, PAK = Pakistan, TAJ = Tajikistan, TKM = Turkmenistan, UZB = Uzbekistan.

Source: Authors' calculations.

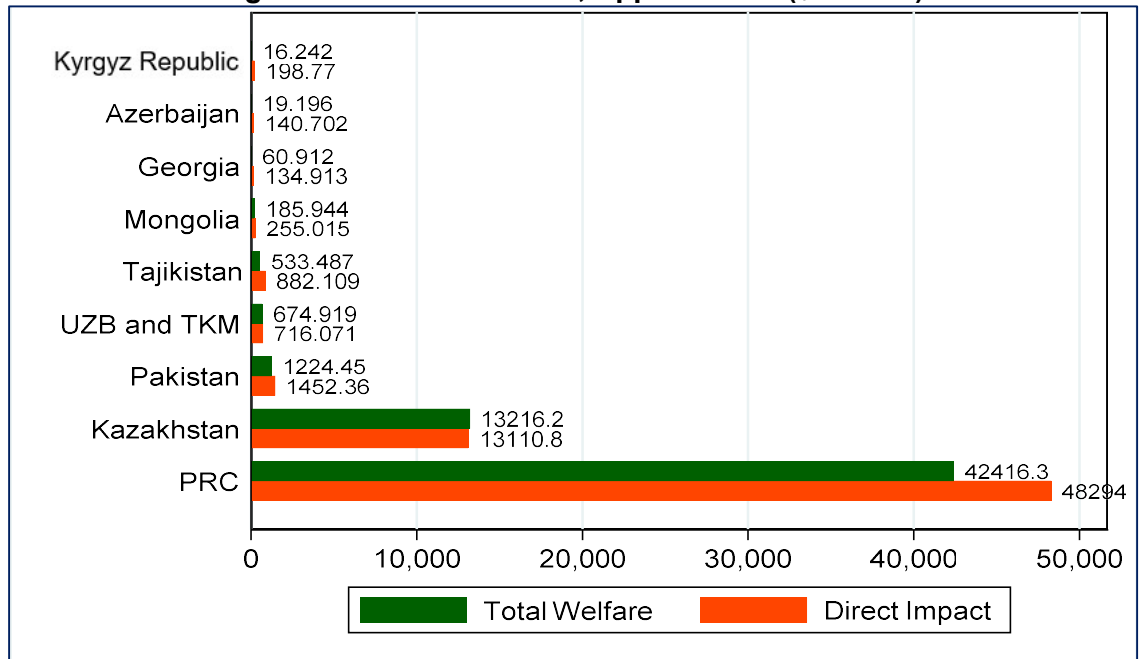
**Figure 17: Welfare Effects, Lower-bound (\$ million)**



PRC = People's Republic of China, TKM = Turkmenistan, UZB = Uzbekistan.

Source: Authors' calculations.

**Figure 18: Welfare Effects, Upper-bound (\$ million)**



PRC = People's Republic of China, TKM = Turkmenistan, UZB = Uzbekistan.

Source: Authors' calculations.

## VI. CONCLUSION

This paper investigates the effects of ADB-funded transportation infrastructure reforms on the transport time and trade in CAREC countries using an integration of GIS, econometric, and CGE analyses. We focus our analysis on the transport reforms, specifically roadways and railways, which lower trade barriers and enrich the connectivity of CAREC countries within the region and across the global markets.

Utilizing a geo-referenced data and GIS analysis, we first calculate the reduction in transport time between capitals and major cities in CAREC countries induced by ADB-funded transport reforms. In doing so, we assess the potential modal substitution between faster and cheaper transport modes that may engender additional savings in transport time. Using a TPM, we evaluate the effects of transport time on both the extensive and intensive margins of trade. Additionally, using a comparative advantage model, we test if the reductions in transport time have larger trade impacts on products that are time-sensitive. We address the potential endogeneity between trade and infrastructure using the average geographical features of trade partners as instruments for the bilateral transport time. Combining the GIS and econometric estimates, we find that the variation in trade impacts across countries results from both the extent of exposure to the infrastructure shocks and the export structure of the country. In particular, the largest trade gains stem from transport time reductions for time-sensitive sectors that are integrated in production chains. Implementing the estimated direct trade impacts in the firm-heterogeneity CGE model in GTAP, we explore the additional endogenous impacts of transport time reductions on trade in the CAREC countries that arise through the changes in prices and number of varieties.

We find that ADB-funded transportation reforms in CAREC countries decrease transport time between city pairs by 1.00% to 2.18% on average. This corresponds to an increment in bilateral trade values for existing exporters by 3.31% and trade participation by 1.21%, on average (upper-bound estimates). The upper-bound scenario supposes that exporters can switch transport modes to take advantage of faster shipping alternatives. A lower-bound estimate is that, on average, bilateral trade values increase by 1.16% for existing exporters and trade participation rises by 0.45%. The lower-bound scenario restricts any modal substitution so that the trade impacts arise due to infrastructure reforms only. We find a sizeable variation across country pairs and sectors in our results: we predict the largest reductions in transport time (and improvements in trade) for countries such as Kazakhstan, the Kyrgyz Republic, the PRC, and Tajikistan, and for time-sensitive products. Using the CGE analysis, we find that trade values for CAREC countries increase by 2.04 to 8.72%, on average, due to additional endogenous effects on trade. We also find a positive change in total welfare for CAREC countries.

However, some uncertainty exist in our estimates. The CAREC project documentations lack significant details on infrastructure investment for some countries, and those limitations will affect trading time. A full assessment necessitates the incorporation of project details on travel speed by mode, existing transport modal shares, border delays, traffic volume, and quality of infrastructure along each trade route. Transportation improvements are just one element of the CAREC program, and reductions in trade barriers such as border delays and trade policy measures may further foster trade relations. Therefore, our findings may provide a conservative estimate of the trade impact of the CAREC program.

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## Trade Effects of Transportation Infrastructure among CAREC Countries

This paper investigates the trade effects of road and rail infrastructure reforms in 11 member countries of the Central Asia Regional Economic Cooperation (CAREC) program. It explains how bottlenecks and border delays hinder trade in the region and shows how improving transportation can free up commerce and make CAREC countries more competitive. Using geographic information systems analysis, the paper highlights how reforms help cut transportation times between key cities and impact on time-sensitive inputs and bilateral trade. It notes countries such as Kazakhstan and Tajikistan as among the most likely to benefit from reduced transportation times.

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