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Estimating Road Freight Transport Costs in Eastern Europe and Central Asia Using Large Shipping Data

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Abstract

The recent global crises, such as the COVID-19 crisis, remind us of the importance of efficient transportation and logistics. Notably, however, even before the crises, some regions were already experiencing a gradual increase in freight costs, with more and more empty trucks observed. The paper recasts light on the question of how road freight costs are determined using large, unique shipping data from Eastern European and Central Asian countries. It finds that economies of scale are significant in both freight weight or load factor and distance. The elasticity with respect to freight weight is particularly high at about 0.3 to 1.0 in absolute terms. Thus, to contain trucking costs, it is important to maximize the load factor through freight consolidation at origins and destinations. The elasticity with respect to distance is relatively modest at 0.04 to 0.16 in absolute terms but still statistically significant, indicating that distance may not necessarily be a constraint on trade and regional integration. Trucking costs also decrease with driving speed, a proxy for efficiency of movements or road conditions. The elasticity is significant for food products (–0.03) and other consumer goods (–0.11). Finally, the paper finds that border crossing adds 3–4 percent to freight costs.

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Estimating Road Freight Transport Costs in Eastern Europe and Central Asia

Using Large Shipping Data

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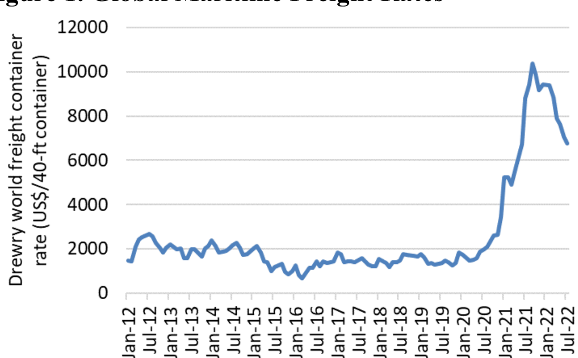
I. Introduction

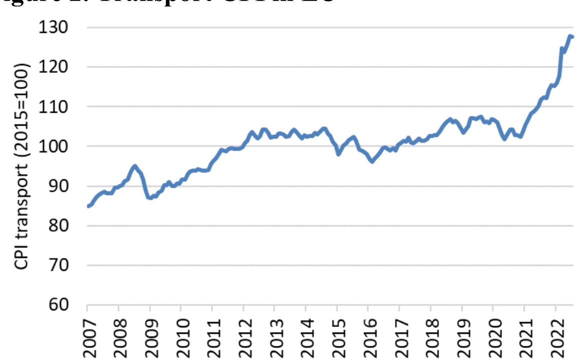
1. In recent years, transportation costs have been increasing all over the world because of various external shocks, such as the Coronavirus Disease 2019 (COVID-19) crisis, reminding us of the importance of efficient transport and trade.[1] Because of the stagnation and faster-than-expected recovery in global trade and outputs, international shipping remains constrained. Shortages continue in logistical equipment, containers, service operators, such as truck drivers and port operators, and cargo vessels (UNCTAD, 2021). Maritime freight rates reached over US$10,000 per 40-foot container in 2021, five times higher than the level prior to the COVID crisis (**Figure 1**). Road transport costs are also increasing. According to Eurostat, the harmonized consumer price index for transport jumped from 106.7 in 2020 to 127.6 in 2022, a 20-percentage point increase for the last two years (**Figure 2**).

Figure 1. Global Maritime Freight Rates



Source: Drewry.

Figure 2. Transport CPI in EU



Source: Eurostat.

2. Notably, however, even before the COVID crisis, some regions, such as Europe, observed an increasing trend of freight costs. Various reasons exist. First, fuel prices increased. Particularly, diesel prices were on average 0.99 euros in 2016 but increased to 1.40 euros in 2019 and about 2 euros in 2022 (**Figure 3**). This had a significant impact on freight rates because diesel costs account for one-third to one-half of the total transport operating costs. Second, truck drivers are insufficient. Aging workforce in the market is a structural challenge, putting more pressure to

[1] The following analysis examines the period from 2010 to 2020. The impact of the COVID crisis may not be reflected sufficiently in our dataset.

increase drivers' wages. While drivers over 55 years old account for 34 percent of the total labor force in this sector in Europe, only 7 percent are under 25 years old (Ti et al., 2022).

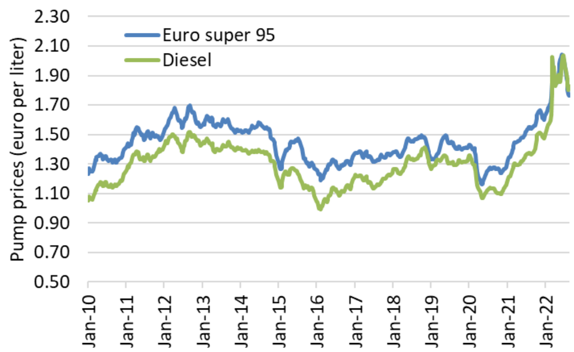
3. Load factor is an important determinant of freight rates. In Europe, the share of road freight kilometers carried by empty vehicles has been increasing especially for international freight (**Figure 4**). From the efficiency point of view, holding everything else constant, freight rates may be higher when there are more empty containers. Freight rates are also determined by the road condition. The higher quality of roads generally leads to lower freight rates. In theory, road user costs, including vehicle operating and maintenance costs and drivers' time costs, can be reduced if roads are well maintained. Road roughness is negatively associated with driving speed (e.g., Alessandroni et al., 2017). However, the relationship among road conditions, traffic speed and freight rates may be complicated by other factors involved, such as the trucking industry's market structure. Given all these factors, it remains open to argument whether overall freight rates increased or declined, and why.

4. The current paper recasts light on the question of how road freight transport costs are determined, using large sample shipping data from Eastern European and Central Asian countries. Since the early 2010s, the region has made significant infrastructure investments to improve interregional connectivity between Europe and East Asia. Despite our general belief that the enhanced connectivity would facilitate regional integration and trade (e.g., ADB, 2020; Kalyuzhnova and Holzhacker, 2021), there is little empirical evidence to the best of my knowledge. The paper takes advantage of unique micro data, which comprises stop-by-stop shipping data in the Central Asia Regional Economic Cooperation (CAREC) member countries, including Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, collected by the Asian Development Bank (ADB).[2] The data is focused on long-distance truck shipments and covers a long period of time from 2010 to 2020, which allows us to evaluate the impacts of long-term infrastructure investment made in the region on freight costs.

[2] See ADB (2014, 2020) for more details. I would like to express my special thanks to the CAREC Corridor Performance Measurement and Monitoring (CPMM) team for sharing relevant raw data.

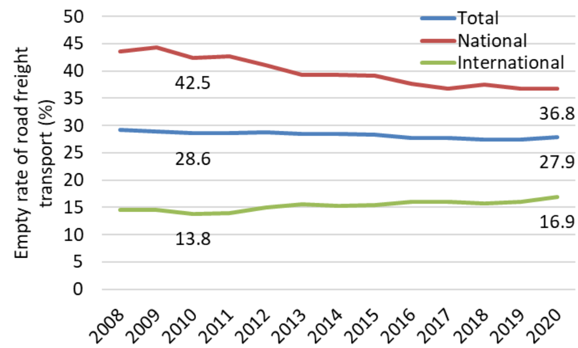
5. The following sections are organized as follows: Section II elaborates on a conceptual theoretical framework and develops our empirical model. Section III describes our data. Section IV presents main estimation results. Section V discusses robustness and some policy implications. Then, Section VI concludes.

Figure 3. Pump Prices in EU



Source: Eurostat.

Figure 4. Empty Rate of Road Freight in EU



Source: Eurostat.

II. Theoretical Background and Empirical Model

6. Freight rates are determined by various factors. From the traditional transport economics point of view, road improvement can reduce fuel costs, vehicle maintenance costs and potential fatality costs. According to the Highway Development and Management Model (HDM-4) road management and evaluation software, road user costs can be reduced by about 15 percent if the road condition measured by the International Roughness Index (IRI) is improved from 8 (interpreted as a road in very poor condition) to 2 (a road in good condition), holding everything else constant (**Figure 5**). Under competitive circumstances, the reduction of transport costs translates into lower prices of transport services. This actually happens in some, but not all, countries (Teravaninthorn and Raballand, 2009). Still, it may depend on various other factors, including logistics, regulations and competitiveness of the trucking industry.

7. From the freight carrier's point of view, load factor is of particular importance to contain their operating costs. Although a high load factor does not necessarily result in high fuel efficiency, i.e., "load factor paradox" (e.g., Arvidsson 2013), it is generally a good indication of high efficiency in freight distribution. In Europe, a large number of road freight kilometers are carried by empty vehicles (e.g., McKinnon 2010; Eurostat 2021). While the average empty rate

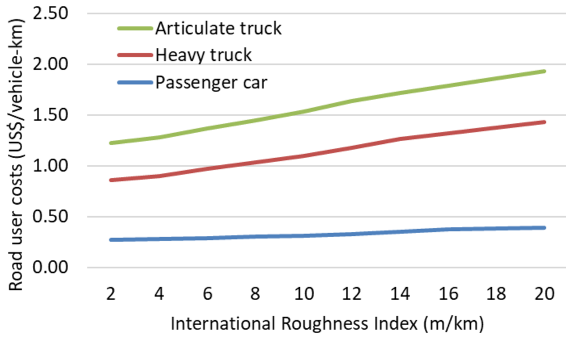
has been declining for domestic freight in recent years, the empty rate for international freight has been increasing, raising concerns about freight inefficiency and high costs at the regional level. The following analysis will examine the potential structural difference between domestic and international shipments.

8. The freight consolidation at origins and destinations is a key determinant of the load factor. Freight rates tend to be lower between a pair of larger cities because of economies of scale and consolidation (e.g., Tsekeris, 2022). In Europe, the road freight rates between Paris and Madrid, two large urban areas with a total population of over 5 million, are much lower than the cost of transporting from Paris to Duisburg, a mid-sized city in Germany with a population of about half a million (**Figure 6**). In addition, the shipping rate from Paris to Duisburg is much lower than that from Duisburg to Paris because the demand for shipments in the former direction is much greater. In other words, it is more difficult to fill an entire trailer at Duisburg.

9. In the urban context, the literature also calls for collaborative freight consolidation (e.g., Arvidsson, 2013; Teo et al., 2014). As transport costs become lower, firms hold less inventory, requiring more frequent and smaller lot orders. This is likely to create traffic congestion in cities. Tsekeris (2022) shows that urban sprawl has a significant impact on general road freight costs in Europe.

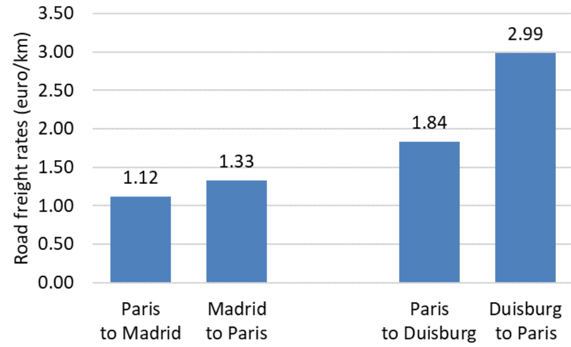
10. Besides freight consolidation, the literature shows that load factors are also determined by other factors, such as trip distance, fleet characteristics, including ownership, market (segment) structure, usage of new technologies (such as Electric Vehicle Management Systems) and efficiency of freight consolidation (e.g., Barla et al., 2010; Abate, 2014; Santen, 2017; Santen and Rogerson, 2018; Zgonc et al., 2019). Our data does not allow capturing these factors directly but unobserved characteristics are controlled for in a statistical manner.

Figure 5. Road Roughness and Road User Costs



Source: HDM4.

Figure 6. Road Freight Rates Between Selected Cities



Source: Ti, Upply and IRU (2022).

11. Given the above background, the following reduced-form regression model is considered:

$$p_{irt} = \beta_0 + \beta_1 speed_{irt} + \beta_2 dist_{irt} + \beta_3 weight_{it} + Z'_{rt}\gamma + type_{irt} + c_t + \varepsilon_{irt} \qquad (1)$$

where p_{irt} is a unit freight cost per ton-kilometer (ton-km), which is paid by truck operator *i* to ship cargo along route *r* at time *t*. Each route is defined by a pair of two locations, e.g., cities and border points, where a shipping carrier stopped. The dependent variable is normalized by cargo volume (more precisely, weight in our dataset) and distance traveled between the two points. Still, to capture the effect of economies of scale in freight operations (e.g., Barla et al., 2010; Abate 2014; Zgonc et al., 2019), the trip distance, denoted by *dist*, is included in the explanatory variables.

12. The model does not have to be linear. Different specifications are examined, including quadratic and logarithmic formulas except for dummy variables. In the logarithmic model, the Battese (1997) specification is used to avoid the logarithm of zero. A traditional approach using a small positive number often causes significant bias. For any dependent variable, *x*, that takes the value of zero, the following transformation is considered:

$$\beta \ln x = \begin{cases} \gamma_1 D_x + \gamma_2 \ln x & \text{if } x > 0 \\ \gamma_1 D_x + \gamma_2 \ln D_x & \text{if } x = 0 \end{cases}$$

where D_x is one when $x = 0$ and zero otherwise.

13. To examine the impact of road conditions, average driving speed is used as a proxy. Significant variation exists in our data (**Figure 7**). It is measured by actual time spent by a vehicle in motion between origin and destination.[3] Driving speed is affected by various factors, such as traffic regulations, vehicle aerodynamics, tire pressure and driving behavior, but the road condition is one of the main determinants (Alessandroni et al., 2017). In our data, the observed driving speed is time-variant, which is important from the empirical point of view. Road conditions change over time (**Figure 8**). While some roads are improved, others are deteriorated.

14. To consider freight efficiency or emptiness of cargo, the freight volume, or more precisely, freight weight (*weight*) is used. In our data, no other variable is available to directly measure the load factor. No information is recorded on truck characteristics. Presumably, however, most trucks have a capacity of 20-25 tons, a normal maximum weight for a twenty-foot equivalent unit (TEU) container (**Figure 9**). If the capacity is more or less constant for many trucks, our weight variable is a good proxy for the load factor. As per the literature, it is expected that *weight* has a negative coefficient, i.e., reducing freight costs.

Figure 7. Distribution of Driving Speeds

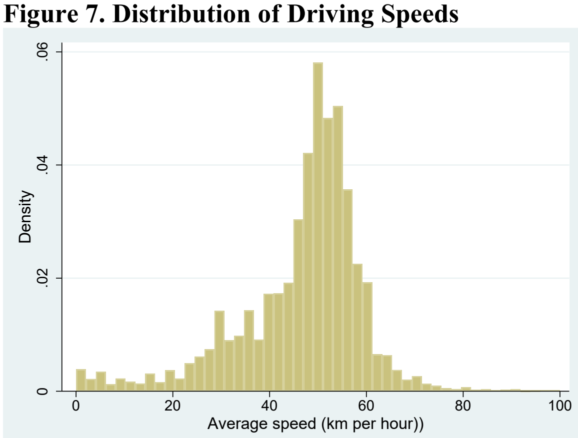
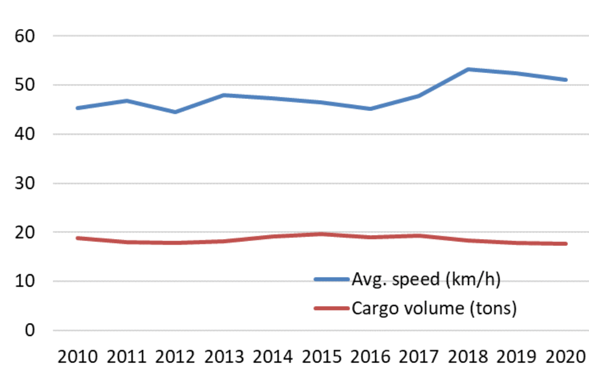
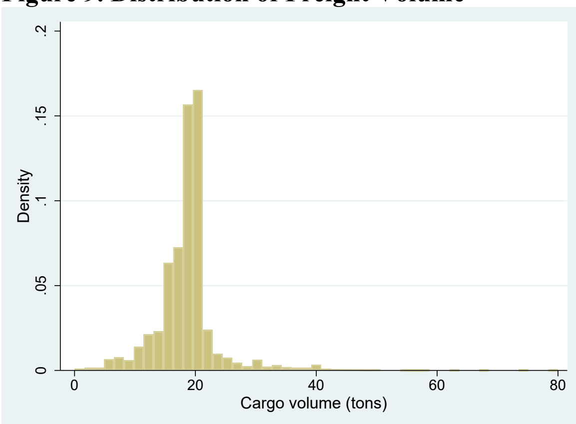


Figure 8. Changes in Speed and Freight Volume



[3] The observed delays at intermediate nodes, such as border crossing and security checkpoints, are excluded from the speed calculation. In the CPMM framework, it is called "speed without delay (SWOD)."

Figure 9. Distribution of Freight Volume



15. To control other route-specific characteristics, two variables are considered in Z.[4] First, a dummy variable for the existence of border crossing is included. This also distinguishes domestic and international cargos. Border crossing often incurs additional time and costs for customs, security clearance and administrative procedures. If this is the case, freight costs are likely to be increased.

16. Second, to capture the topographic complexity of each route, the difference in elevation between origin and destination is calculated. Different routes are differently characterized from the geographic point of view. The elevation difference aims at measuring the hilliness of a route. Certain areas, for instance, in Kyrgyzstan and Tajikistan, are very mountainous. Certainly, fuel efficiency would likely vary across routes in those areas.

17. Freight costs may also differ depending on type of commodity. To test such a possibility, a set of commodity-specific dummy variables are included, *type*. Given the country context, cargos are classified into six groups: (i) nearly empty cargo (less than 100 kg), (ii) agricultural commodities and food products, (iii) clothing, apparel and textiles, (iv) consumption and other goods, (v) equipment (including vehicles), and (vi) minerals, metals and materials. Holding

[4] Other route-specific characteristics, such as the market size of origins and destinations, and the horizontal geographic complexity measured by the ratio of road distance to straight-line distance, were also included and examined in an earlier version of the paper. The literature suggests the potentially important impacts of asymmetric market distribution between origins and destinations on the ability of freight consolidation (e.g., Ti et al., 2022; Tsekeris, 2022). The load factor normally increases with market size (e.g., Barla et al., 2010; Abate, 2014). However, these variables were dropped for simplification purposes.

everything else constant, freight costs may be higher if cargos are perishable, such as food. The empty cargos are used as a baseline.

18. Finally, the time-specific fixed-effects, c_t, are included. The data covers 11 years, from January 2010 to December 2020. About 130 year-month dummy variables are created with January 2010 used as a baseline. The coefficients will reveal the time trend of average freight costs over the sample period.

III. Data

19. The main data comes from the CAREC Corridor Performance Measurement and Monitoring (CPMM) database collected by ADB. The analysis uses data for seven countries in Eastern Europe and Central Asia: Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. The region is of particular interest because many large transport investments have been made to improve road and rail connectivity since the early 2010s. For instance, Kazakhstan implemented a massive infrastructure investment program, Nurly Zhol, to redevelop public infrastructure to connect its main cities, logistics centers and free-trade zones to the border crossings, including ports on the Caspian Sea dry ports. The country spent about US$36.6 billion for five years: 2013-2017 (UNECE, 2019). By the same token, the entire region is expected to be reconnected for more regional trade and integration. Notably, however, there are only a few micro studies that examined transport freight costs at the regional level. Persyn et al. (2022) find that the expected impact of increased road user costs on road freight prices is particularly high in Eastern Europe.

20. Originally, the CPMM database contains over 187,000 observations, covering both road and rail shipments. Excluding data with missing information and apparent outliers,[5] 51,137 road shipment data are used. A total of 8,952 carriers transported cargos among 397 locations. Each route is georeferenced. Note that the database is developed at the stop-by-stop level. Even on the

[5] To exclude outliers, the letter-value display analysis was used, which identifies extreme values in the tails of the distribution that fall outside of three times the interquartile range (IQR) for each variable.

same road segment, some shipping carriers may drive faster or transport cargos at lower prices than others.

21. The summary statistics are shown in **Table 1**. Our dependent variable is the road transport freight costs in U.S. cents per km. The freight costs include both vehicle transport costs, such as drivers and fuel costs, parking fees and minor repairs, and other trade and administrative costs at intermediate nodes, such as border crossing and traffic police checkpoints. All kinds of expenditures are included (see ADB (2014)). The costs are converted to U.S. cents and normalized to 2010 constant dollars using the U.S. consumer price index. The average freight cost is 4.57 U.S. cents per ton-km with a standard deviation of 2.41. It is distributed in a highly skewed manner around 4 to 5 cents (**Figure 10**). If a heavy truck with a maximum capacity of 20 tons is fully loaded, the average shipping cost for 100 km distance would be approximately US$91.

22. The distance, average speed and freight volume data also come from the CAREC CPMM database. Our sample is focused on long-haul cargos. The average distance is 170 km. The average speed is 50 km per hour. Note that the speed may differ across routes even though the freight operator, i.e., driver is the same. On the other hand, the freight volume is generally unchanged across the routes as long as they constitute the same shipment. The average cargo weight is 18.2 tons. As discussed above, most common vehicles in our sample data are 20-ton trucks. Thus, this variable is heavily concentrated to 20 tons or less.

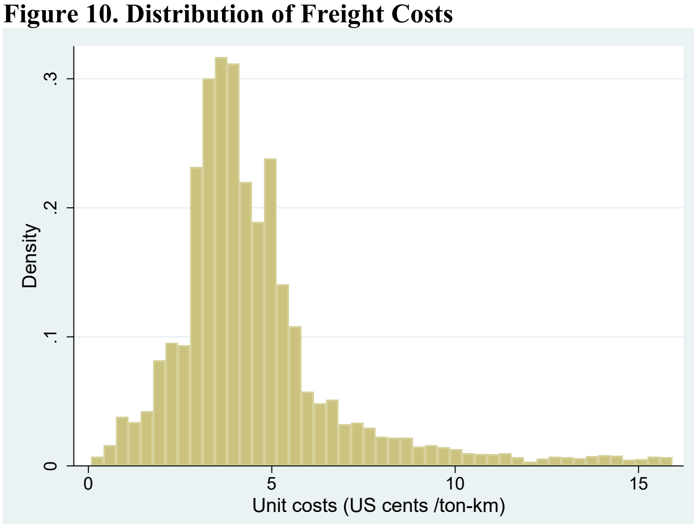
23. The region is diverse in topographic complexity. The average vertical difference in elevation between origin and destination is about 144 meters. About 20 percent are international shipments.

24. Finally, our data comprises a wide variety of commodities and goods. All cargos are classified into five groups in addition to empty cargo: (i) agricultural commodities and food products, (ii) clothing, apparel and textiles, (iii) consumption and other goods, (iv) equipment (including vehicles), and (v) minerals, metals and materials. In our sample, agricultural commodities and food products account for about 46 percent.

Table 1. Summary Statistics

Variable	Abb.	Obs	Mean	Std. Dev.	Min	Max
Road freight costs (U.S. cents per ton-km)	*p*	51,137	4.57	2.41	0.07	15.92
Average driving speed (km per hour)	*speed*	51,137	50.00	8.85	0.60	94.00
Road distance traveled between origin and destination (km)	*dist*	51,137	171.99	101.17	8.00	600.00
Freight weight (tons)	*weight*	51,137	18.17	2.87	0.31	29.56
Difference in elevation between origin and destination (m)	*elev*	51,137	143.92	162.26	0.00	1159
Dummy for international freight	*crossborder*	51,137	0.20	0.40	0	1
Type of commodity:						
Nearly empty cargo		51,137	0.00006	0.006	0	1
Clothing, apparel and textile	*cloth*	51,137	0.202	0.402	0	1
Industrial and transport equipment and parts	*equipment*	51,137	0.128	0.335	0	1
Agricultural commodities and food products	*food*	51,137	0.459	0.498	0	1
Minerals, metal products and materials	*mineral*	51,137	0.092	0.290	0	1
Other consumer goods	*goods*	51,137	0.118	0.323	0	1

Figure 10. Distribution of Freight Costs



IV. Main Estimation Results

25. The ordinary least squares (OLS) regression is performed with three different specifications: Linear, quadratic and logarithmic. The estimated results are shown in **Table 2**. All the coefficients are broadly consistent with our prior expectation. First of all, it is found that traffic speed, which we interpret as a proxy for road conditions, has a negative impact on freight rates. All the coefficients are negative and statistically significant, meaning that efficient freight

movements, potentially because of roads in good conditions, lead to lower freight costs. The elasticity varies from -0.29 to -0.49, depending on the specification (**Table 3**). The finding is consistent with the traditional assumption for transport infrastructure investment: Good roads reduce transport costs (e.g., Lokshin and Yemtsov, 2005; Teravaninthorn and Raballand, 2009; Danida, 2010). It is an important addition to the literature to quantify the magnitude of the impact. The sensitivity of the estimation results to model specification may be able to understand that the potential impact of road conditions is complex, and perhaps, highly nonlinear.

26. Second, the results suggest that economies of scale in both distance and load are important for shipping carriers to contain freight transport costs. The coefficients of *dist* are negative and statistically significant. In the logarithmic case, it is estimated at -0.064. Thus, the longer distance, the lower freight transport costs. In addition, freight transport costs reduce with cargo weight. The coefficient tends to be large (in absolute terms) and is 0.66 in the logarithmic model. Recall that the weight variable can be interpreted as a proxy for the load factor because the truck capacity is 20 tons for most shipping carriers in our data. Thus, freight costs are lowered as load factors increase, as observed in the literature (e.g., Abate 2014; Tsekeris 2022).

27. For other characteristics of shipments, it is clear that topology matters to freight transport costs. Shipping costs are higher in hilly areas. The elevation variable (*elev*) has positive coefficients regardless of specification. In the logarithmic case, it is estimated at 0.049, meaning that the freight costs increase by about 0.5 percent if the vertical difference in elevation between origin and destination points increases by 10 percent. This is intuitively acceptable because driving speeds, particularly for heavy duty trucks, tend to be constrained on a hilly or mountainous terrain, causing more fuel and time costs.

28. As expected, border crossing adds to freight costs. The coefficient is significantly positive regardless of specification. Despite recent efforts toward integrating and simplifying border crossing procedures, it seems that border crossing remains costly in the region. According to the linear and quadratic models, it adds an additional cost of 0.15 or 0.17 U.S. cents per ton-km, which is about 3-4 percent of average freight unit costs.

29. To examine which variable has the largest influence on freight costs, all the elasticities are evaluated at sample means (**Table 3**). The largest elasticity (in absolute terms) is found for the weight variable. This is robust regardless of specification. The elasticity is estimated at 0.59 to 0.77. This confirms the particular importance of load factors to determine road freight costs. The elasticity associated with driving speed, a proxy for road conditions, is also high at 0.29 to 0.46. It means that holding everything else constant, a 10 percent increase in speed would reduce freight costs by 3 to 5 percent. Then, the elasticity of distance follows, which is relatively small at 0.04 to 0.06.

Table 2. OLS estimation results: Pooled model

	Linear		Quadratic		Logarithmic	
	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
speed	-0.042	(0.002) ***	-0.338	(0.011) ***		
speed^2			0.0031	(0.0001) ***		
ln *speed*					-0.395	(0.015) ***
dist	1.6E-04	(1.3E-04)	-2.3E-03	(3.6E-04) ***		
dist^2			3.4E-06	(6.6E-07) ***		
ln *dist*					-0.064	(0.005) ***
weight	-0.194	(0.005) ***	-1.040	(0.031) ***		
weight^2			0.025	(0.001) ***		
ln *weight*					-0.664	(0.015) ***
elev	2.1E-03	(7.9E-05) ***	9.0E-04	(1.7E-04) ***		
elev^2			8.3E-07	(3.2E-07) ***		
ln *elev*					0.049	(0.001) ***
D_elev					-0.076	(0.078)
crossborder	0.152	(0.025) ***	0.170	(0.025) ***	0.024	(0.004) ***
cloth	-1.168	(0.269) ***	3.496	(0.340) ***	-0.029	(0.064)
equipment	-0.241	(0.269)	4.153	(0.339) ***	0.141	(0.064) **
food	-1.116	(0.270) ***	3.522	(0.341) ***	0.005	(0.064)
mineral	-0.154	(0.273)	4.333	(0.342) ***	0.107	(0.065) *
goods	-0.426	(0.269)	3.973	(0.339) ***	0.019	(0.064)
constant	9.533	(0.270) ***	19.185	(0.393) ***	4.650	(0.086) ***
Obs.	51,137		51,137		51,137	
R-squared	0.2526		0.3293		0.3337	
F stat.	129.66		163.15		160.26	
No. of time dummy variables	131		131		131	

Note: The dependent variable is freight rate, *p*. for the first two models, and the log of freight rate, ln *p*, for the last column model. Robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10, 5 and 1 percent level, respectively.

Table 3. Estimated elasticity: Pooled model

	Linear		Quadratic		Logarithmic	
Variable	Elasticity	Std. Err.	Elasticity	Std. Err.	Elasticity	Std. Err.
speed	-0.464	(0.021) ***	-0.291	(0.021) ***	-0.395	(0.015) ***
dist	0.006	(0.005)	-0.043	(0.006) ***	-0.064	(0.005) ***
weight	-0.773	(0.020) ***	-0.593	(0.019) ***	-0.664	(0.015) ***
elev	0.065	(0.002) ***	0.036	(0.003) ***	0.049	(0.001) ***

*, ** and *** indicate statistical significance at the 10, 5 and 1 percent level, respectively.

30. After controlling all the observables, it seems that the freight costs did not change substantially during the overall sample period. The estimated coefficients of the time-specific fixed-effects are plotted over time (**Figure 11**). There are clear structural differences in our data, possibly caused by changes in data collection method. In a subset of the data for the period from 2013 to 2018, the freight costs declined consistently. In more recent years, there was no significant time-specific effect on freight costs. This does not necessarily contradict the fact that the nominal transport costs declined over time. The average transportation costs on the regional corridors were indeed halved from US$1,400 per 20-ton cargo per 500 km in 2014 to US$700 in 2019 (ADB, 2020). The change in nominal costs is explained by all the observables in the equation, such as increased speed and increased share of international freight.

31. Finally, most of the commodity-type-specific fixed effects are found to be significant. The null hypothesis that all the coefficients are the same can be easily rejected. The F-test statistics are estimated at 357.15 and 222.75 for the linear and quadratic models, respectively. It is estimated at 212.78 in the logarithmic case. Thus, it is likely that the freight costs are determined differently across types of commodities. There is a clear tendency that the shipping costs for light merchandises, such as apparel, consumer goods and food products, are lower than those for heavy materials and industrial equipment. The coefficients are plotted using the logarithmic estimation result (**Figure 12**).

Figure 11. Estimated time-specific fixed-effects

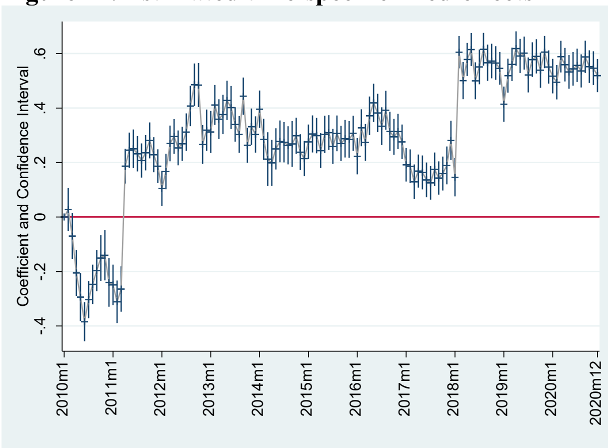
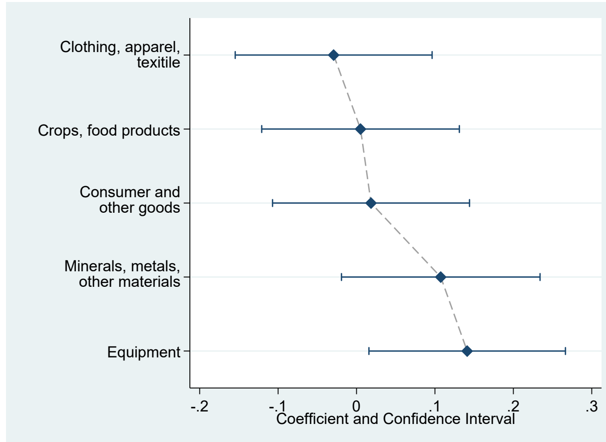


Figure 12. Estimated commodity specific fixed-effects



V. Heterogeneity and Robustness

32. As discussed above, there seems to be a systematic difference in freight costs across commodities. To investigate potential heterogeneity in freight cost determinants, the sample data is divided into five groups: (i) clothing and apparel, (ii) equipment and vehicles, (iii) agricultural commodities and food, (iv) minerals and metals, and (v) consumer goods. The logarithmic model is separately estimated by applying OLS (**Table 4**).[6] The results are broadly consistent with the above, but some coefficients are different among groups of commodities. For instance, driving speed or road conditions matter most for equipment and minerals (**Figure 13**). For other types of shipments, i.e., food products and consumer goods, the elasticities are small. It can be interpreted to mean that production-oriented capital goods are more sensitive to delivery efficiency than consumer goods.

33. For shipping distance, it is found that the freight cost increases with distance for all kinds of merchandises but equipment. The elasticities are small for clothing and food products. Thus, the freight cost does decrease with distance, but very marginally. This may make sense because some agricultural commodities are perishable, and thus, it is costly to transport for a long

[6] The estimation results are largely similar for the linear and quadratic models. Thus, the only results from the logarithmic estimation are shown in the table.

distance. On the other hand, there are significant economies of distance expected for shipping minerals and consumer goods, which are generally unperishable.

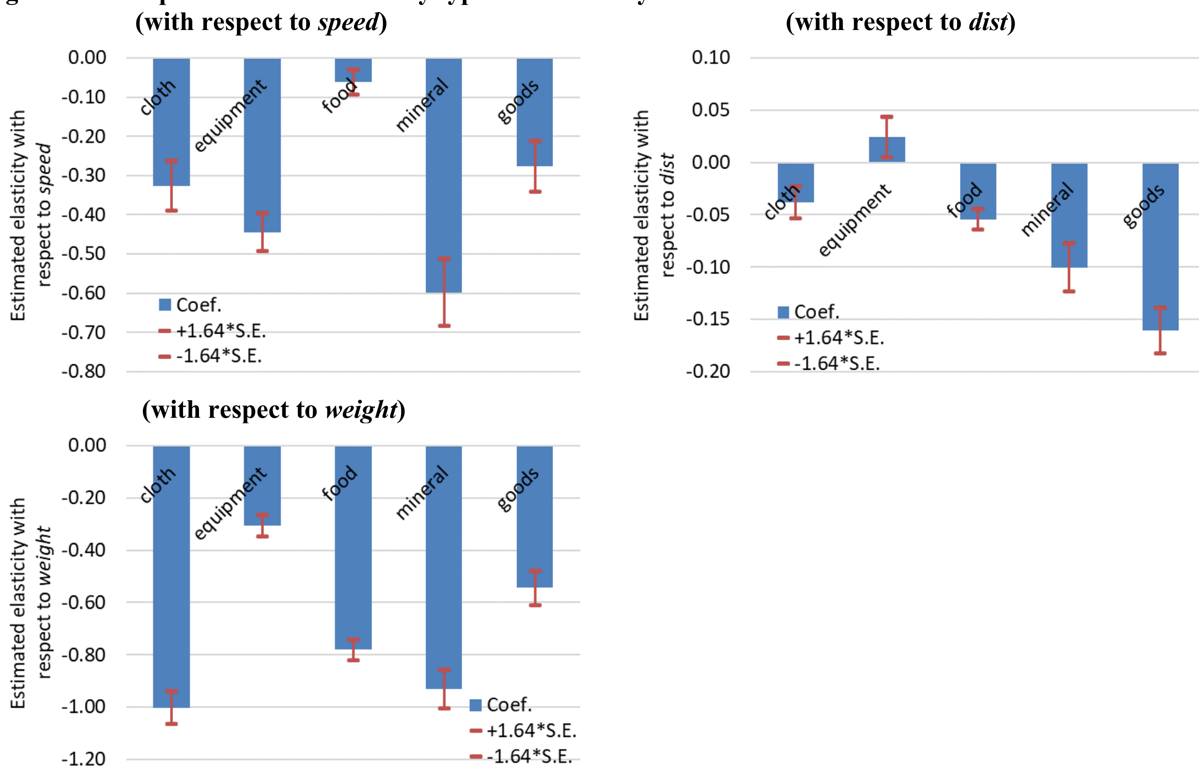
34. Regardless of type of commodity, freight costs are very elastic to cargo weight or load factor. The elasticity varies from 0.3 to 1.0, depending on commodities. Heavy, bulky commodities, such as minerals, materials and agricultural products, look more sensitive. For these goods, freight efficiency and consolidation are important to lower freight costs.

Table 4. Separate OLS estimation results by type of commodity

Commodity type:	*cloth*		*equipment*		*food*		*mineral*		*goods*	
	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
ln *speed*	-0.326	(0.039) ***	-0.445	(0.029) ***	-0.061	(0.019) ***	-0.599	(0.052) ***	-0.277	(0.039) ***
ln *dist*	-0.038	(0.009) ***	0.024	(0.012) ***	-0.054	(0.006) ***	-0.100	(0.014) ***	-0.161	(0.013) ***
ln *weight*	-1.003	(0.039) ***	-0.305	(0.025) ***	-0.781	(0.024) ***	-0.931	(0.046) ***	-0.544	(0.040) ***
ln *elev*	0.077	(0.003) ***	0.070	(0.004) ***	0.017	(0.002) ***	0.106	(0.006) ***	0.064	(0.006) ***
D_elev	0.017	(0.171)	-0.381	(0.375)	0.742	(0.578)	0.868	(0.328) ***	-0.059	(0.067)
crossborder	-0.024	(0.009) ***	0.112	(0.011) ***	-0.013	(0.004) ***	0.058	(0.015) ***	0.127	(0.018) ***
constant	4.873	(0.182) ***	3.239	(0.158) ***	4.082	(0.111) ***	5.889	(0.270) ***	4.620	(0.210) ***
Obs.	10,347		6,565		23,458		4,729		6,035	
R-squared	0.4819		0.3655		0.3824		0.4220		0.4659	
F stat.	65.32		34.48		131.00		…		97.37	
No. of time dummy variables	131		131		131		131		131	

Note: The dependent variable is freight rate in logarithm, ln *p*. Robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10, 5 and 1 percent level, respectively.

Figure 13. Comparison of elasticities by type of commodity



35. Although the above estimation results are fairly robust regardless of model specification, one may wonder if there are any omitted variables that determine the freight costs. In the literature, for instance, fleet characteristics and ownership affect the load factor (e.g., Abate, 2014). The efficiency in freight distribution network may also be relevant from a broader logistic arrangement perspective (e.g., McKinnon, 2010; Arvidsson, 2013). To check this omitted variable issue, the freight-carrier-specific fixed-effects are incorporated in the model. Note that the unit of observation is stop-by-stop shipment. Our data are not panel but cross-sectional at different points of time. Every month each shipping carrier records where it operates, more precisely, from where to where to transport cargo. It may stop multiple times. Therefore, unless there is no intermediate stop, the carrier-specific fixed-effects can be included to control for their time-invariant, unobservable characteristics, such as ownership structure or fleet attributes.

36. The results are found to be broadly the same as the above (**Table 5**). The inferred elasticities are also calculated (**Table 6**). The results indicate that the freight costs are likely to decrease with

and travel distance and increase with the difference in elevation, which is consistent with the above estimation without the fixed effects.

37. One distinct outcome may be that the coefficient associated with driving speed turned out to be positive, not negative, or statistically insignificant. First, it means that there must be unobservable carrier-specific characteristics that systematically affect driving speed, such as fleet age, other technical vehicle attributes and carriers' driving behavior.

38. Second, there is a possibility that the effect of speed or transport efficiency may be heterogeneous across different types of commodities, thus, offsetting the impact. To examine this possibility, the fixed-effects regression is separately performed for each of the subgroups. It is found that the impact of driving speed is negative and significant for food and other consumer goods (**Table 7**). The freight costs for these commodities seem to be particularly sensitive to transport efficiency. For other merchandises, driving speed may not matter.

Table 5. Freight carrier fixed effects model

	Linear			Quadratic			Logarithmic		
	Coef.	Std.Err.		Coef.	Std.Err.		Coef.	Std.Err.	
speed	0.002	(0.001)	**	3.3E-04	(4.0E-03)				
speed^2				9.5E-06	(4.2E-05)				
ln *speed*							-0.014	(0.009)	
dist	-1.7E-03	(5.9E-05)	***	-1.8E-03	(1.4E-04)	***			
dist^2				3.0E-07	(3.0E-07)				
ln *dist*							-0.050	(0.002)	***
elev	1.1E-03	(2.4E-05)	***	2.3E-03	(5.4E-05)	***			
elev^2				-2.2E-06	(7.7E-08)	***			
ln *elev*							0.050	(0.001)	***
D_elev							-0.239	(0.033)	***
crossborder	0.192	(0.008)	***	0.172	(0.008)	***	0.037	(0.002)	***
constant	3.123	(0.042)	***	3.070	(0.097)	***	1.214	(0.037)	***
Obs.	51,137			51,137			51,137		
R-squared	0.947			0.9479			0.8857		
F stat.	...			...			...		
No. of carrier dummy variables	8952			8952			8952		

Note: The dependent variable is freight rate, *p*. for the first two models, and the log of freight rate, ln *p*, for the last column model. Robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10, 5 and 1 percent level, respectively.

Table 6. Estimated elasticity based on freight carrier fixed effects models

	Linear			Quadratic			Logarithmic		
Variable	Elasticity	Std. Err.		Elasticity	Std. Err.		Elasticity	Std. Err.	
speed	0.023	(0.009)	**	0.014	(0.009)		-0.014	(0.009)	
dist	-0.065	(0.002)	***	-0.063	(0.002)	***	-0.050	(0.002)	***
elev	0.034	(0.001)	***	0.053	(0.001)	***	0.050	(0.001)	***

*, ** and *** indicate statistical significance at the 10, 5 and 1 percent level, respectively.

Table 7. Freight carrier specific fixed effects models by type of commodity

Commodity type:	*cloth*			*equipment*			*food*			*mineral*			*goods*		
	Coef.	Std.Err.		Coef.	Std.Err.		Coef.	Std.Err.		Coef.	Std.Err.		Coef.	Std.Err.	
ln *speed*	-0.012	(0.022)		0.028	(0.027)		-0.028	(0.011)	**	0.082	(0.031)	***	-0.108	(0.038)	***
ln *dist*	-0.059	(0.005)	***	-0.044	(0.007)	***	-0.042	(0.003)	***	-0.086	(0.008)	***	-0.085	(0.009)	***
ln *elev*	0.081	(0.002)	***	0.054	(0.004)	***	0.026	(0.001)	***	0.085	(0.004)	***	0.053	(0.003)	***
D_elev	-0.077	(0.049)		-0.257	(0.222)		0.013	(0.015)		0.143	(0.319)		-0.220	(0.021)	***
crossborder	-0.013	(0.007)	**	0.054	(0.005)	***	0.049	(0.002)	***	0.023	(0.007)	***	0.107	(0.009)	***
constant	1.434	(0.094)	***	1.772	(0.113)	***	1.349	(0.047)	***	1.238	(0.117)	***	1.969	(0.148)	***
Obs.	10,347			6,565			23,458			4,729			6,035		
R-squared	0.8162			0.8778			0.8882			0.9027			0.9304		
F stat.	...			...			...			...			...		
No. of carrier dummy variables	1581			1227			3548			998			1593		

Note: The dependent variable is freight rate in logarithm, ln p. Robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10, 5 and 1 percent level, respectively.

39. Another question of interest may be related to heterogeneity between domestic and international shipments. The literature points out an important difference in empty vehicle rate between domestic and international cargos in Europe. To analyze potential structural differences, the sample data is divided by the presence of border crossing, *bordercrossing*. The results are somewhat mixed but consistently indicate that the estimated impacts of most of the determinants are slightly greater for domestic shipments than international cargos (**Table 8**). For instance, domestic shipments generally look more sensitive to shipping speed. The impact of cargo weight is also greater for domestic shipping. All of these effects may provide greater incentive for shipping carriers to consolidate more cargos, reducing empty trucks.

Table 8. OLS and fixed effects models by border crossing

	OLS w/o carrier FE						Carrier FE models					
	crossborder=0			*crossborder*=1			*crossborder*=0			*crossborder*=1		
	Coef.	Std.Err.		Coef.	Std.Err.		Coef.	Std.Err.		Coef.	Std.Err.	
ln *speed*	-0.437	(0.018)	***	-0.330	(0.026)	***	-0.055	(0.015)	***	-0.036	(0.009)	***
ln *dist*	-0.011	(0.005)	**	-0.283	(0.009)	***	-0.050	(0.003)	***	-0.010	(0.005)	*
ln *weight*	-0.677	(0.017)	***	-0.652	(0.025)	***						
ln *elev*	0.054	(0.002)	***	0.035	(0.003)	***	0.049	(0.001)	***	0.003	(0.001)	***
D_elev	-0.138	(0.069)	**	1.296	(0.144)	***	-0.271	(0.031)	***	0.034	(0.014)	**
cloth	0.095	(0.066)		-0.167	(0.016)	***						
equipment	0.239	(0.066)	***	0.061	(0.019)	***						
food	0.141	(0.067)	**	-0.202	(0.016)	***						
mineral	0.206	(0.067)	***	-0.005	(0.020)							
goods	0.108	(0.066)	*									
constant	4.508	(0.099)	***	5.273	(0.146)	***	1.727	(0.069)	***	1.382	(0.039)	***
Obs.	40,922			10,215			40,922			10,215		
R-squared	0.3304			0.4838			0.8897			0.9757		
F stat.	155.17			49.77			...			...		
No. of time dummy variables	131			131			0			0		
No. of carrier dummy variables	0			0			8149			4869		

Note: The dependent variable is freight rate in logarithm, ln *p*. Robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10, 5 and 1 percent level, respectively.

40. Finally, one may also be interested in seeing how the observed freight transport costs are spatially distributed and thus, how local economies in the region could benefit from road infrastructure investment. The above-estimated elasticities are important to discuss how they are determined and how they can be reduced. However, there is no spatial dimension. From the data

sample point of view, the above analysis is only focused on road freight along the major regional corridors, which are normally used by long-haul shipping operators. The local economies are also considered to benefit from them.

41. Using the same data and calculated freight costs, spatial network analysis is carried out to visualize the change in regional transport connectivity over the sample period. Over 800 origin and destination cities are georeferenced (**Figure 14**). About 180,000 shipping routes are also spatially identified based on OpenStreetMap. When more than one freight cost is observed for a particular road, the average cost is calculated. If there is no data observed, the normative speeds and transport costs in the region are assumed, depending on road classification.[7] Then, using spatial software, the minimum transport costs are calculated to bring one ton of cargo to one of the nearest major cities. Fifty populated areas in the region are considered (**Figure 15**).[8]

42. The infrastructure improvement along major corridors influenced local market accessibility in the region. The impacts differ across locations and over time. The changes in freight costs are generally modest. The market accessibility in terms of costs deteriorated in the early 2010s, improved between 2013 and 2016, and then, deteriorated again toward the late 2010s (**Figure 16**). Notably, certain areas, such as the CAREC Corridor 2 through Kyrgyzstan, Tajikistan and Uzbekistan, always have better accessibility than others. While local accessibility has been changed in a particular locality, the overall trend of connectivity remains broadly unchanged from the regional perspective.

Figure 14. Origin and destination cities in data

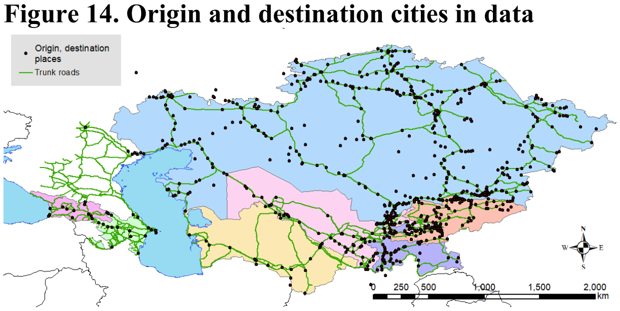
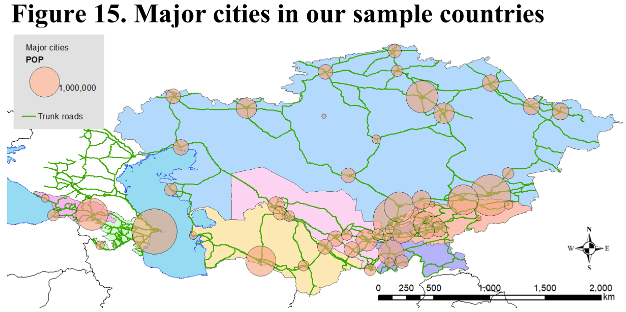


Figure 15. Major cities in our sample countries

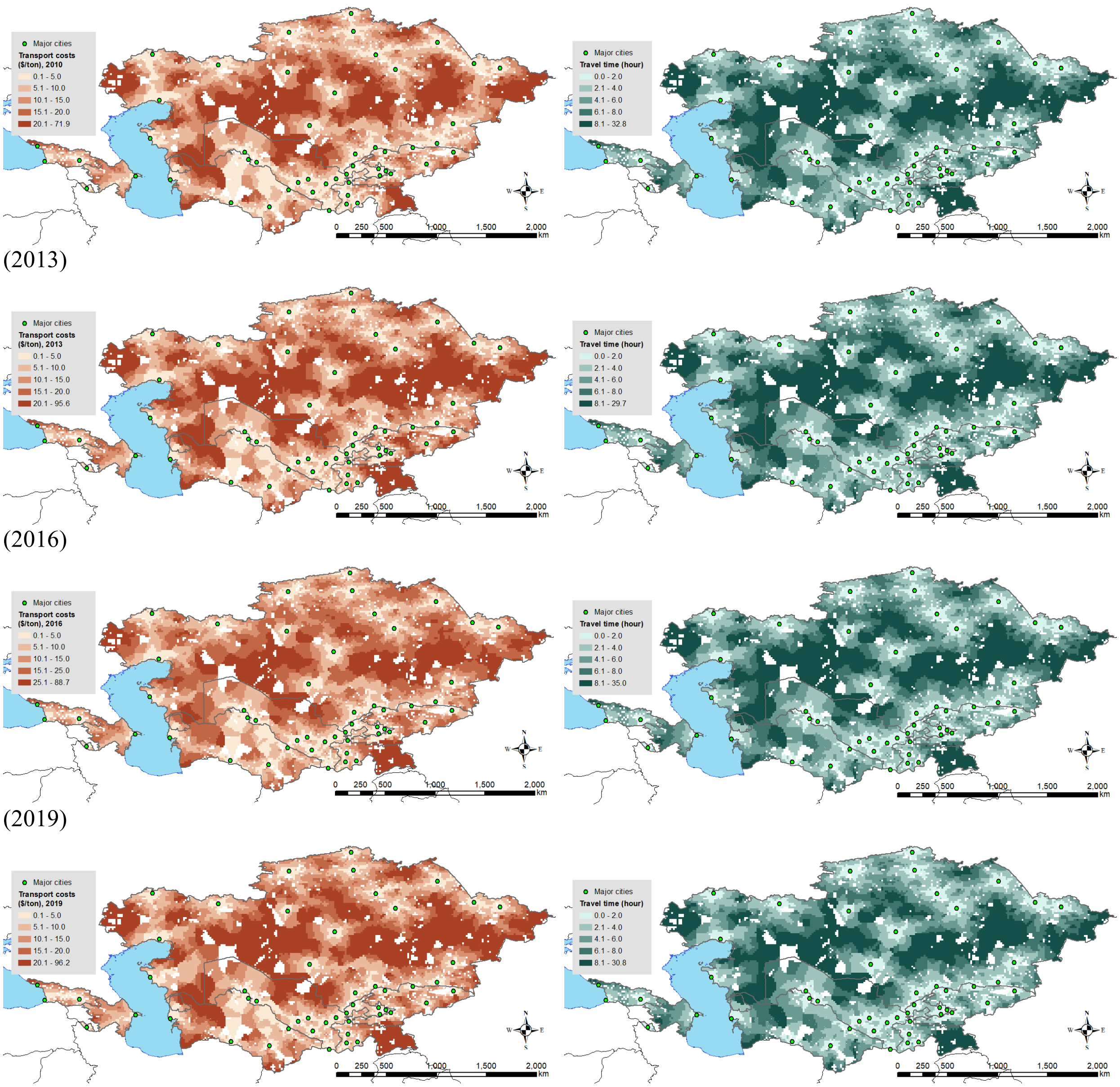


[7] Average speed is assumed to be 40, 30 and 25 km per hour for primary, secondary and tertiary roads, respectively. Transport costs are 9, 10 and 12 U.S. cents per km-ton. The presumption is that the conditions of the shipping routes that are used and recorded in our sample are better than those of non-sampled roads.
[8] According to ArcGIS Hub World Cities.

Figure 16. Change in freight costs and travel times to the nearest major city

Freight costs Travel time

(2010)



VI. Conclusion

43. Transportation costs have been increasing all over the world, especially after the COVID-19 crisis and the Russian Federation–Ukraine conflict began. In Europe, the freight prices increased by 20 percent in the last two years. Notably, however, even before the crises, road freight rates had been gradually increasing in the European region since mid-2010. It has been

long discussed that the road freight efficiency has been deteriorated with more empty trucks observed.

44. The paper recast light on the question of how road freight costs are determined using very large, unique shipping data from Eastern Europe and Central Asia. The data covers over 10,000 shipping operators during the period from 2010 to 2020. Freight costs and time, and other basic characteristics were recorded for over 83,000 shipping routes observed.

45. It was found that economies of scale in both volume and distance matter to freight transport costs. The elasticity with respect to freight volume (tonnage) is high at about 0.3 to 1.0. Thus, the load factor is an important element to determine freight costs. The elasticity of distance is relatively small but significant. It varies from 0.04 to 0.16, depending on specification. Longer distance shipping tends to be cheaper. The elasticities also differ across types of commodities.

46. The impact of speed or the quality of roads looks complex and heterogeneous among different types of commodities. According to the OLS results, transport efficiency matters to capital goods, such as equipment, minerals, metals and materials. On the other hand, consumer goods, agricultural commodities and food products are less sensitive to driving speed. However, it seems that there exist important unobservables that affect both driving speed and freight costs. When the carrier-specific fixed-effects are incorporated, it is found that the transport costs decrease with driving speed for particular types of cargos, such as agricultural commodities, food products, and other consumer goods. The elasticities are estimated at 0.03 to 0.11. If observed driving speed is considered as a proxy for road conditions, it can be concluded that the significant road corridor investment in the region contributed to increasing shipping efficiency and lowering average freight costs.

47. There are other important determinants of freight costs, including terrain conditions, such as elevation. In mountainous areas, freight costs tend to be higher. In the region, there is considerable variation in freight costs. Some areas have better accessibility than others. In general, the observed changes in freight costs look relatively modest. Local economies are expected to benefit more from the corridor infrastructure improvement over the long term.

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