Domestic Road Infrastructure and International Trade: Evidence from Turkey*

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Abstract

Drawing on the large-scale public investment in roads undertaken in Turkey during the 2000s, this paper contributes to our understanding of how internal transportation infrastructure affects regional access to international markets. Using data on international trade of Turkish provinces and the change in the capacity of the roads connecting them to the international gateways of the country, we estimate the distance elasticity of trade associated with roads of varying capacity. Three key results emerge. First, the cost of an average shipment over a high-capacity expressway is about 70 percent lower than it is over single-lane roads. Second, the present value of a 10-year stream of trade flows generated by a one-dollar investment in road infrastructure ranges between \$0.7 and \$2. Third, the reduction in transportation costs is greater the more transportation-sensitive an industry is. To the extent that efficient logistics enable countries to take part in global supply chains and exploit their comparative advantages, our findings have important developmental implications.

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1 Introduction

Poor domestic transportation infrastructure in developing countries is often cited as an important impediment for accessing international markets. Yet, evidence on how a major improvement in the transport network of a country affects the volume and composition of its international trade is scarce. We fill this gap by estimating the impact of a recent large-scale public investment in Turkey aimed at improving the quality of the road network. Our main finding is that, by reducing the cost of shipping, high-capacity expressways improved the foreign market access of regions remote from the ports.

A typical international shipment involves both domestic and international transportation with a possible transhipment across different modes at a harbor, an airport, or a border crossing. Quantitative models of international trade rarely distinguish these separate segments. Bilateral distances used in the estimation of gravity equation are typically the distances between the main cities of countries. While measures taking into account internal distances are available (Redding and Venables 2004), they do not explicitly control for the quality of transportation infrastructure which is clearly important in determining domestic freight costs besides distance.

Intuition and evidence suggest that the domestic component may account for a nonnegligible part of the overall cost of shipping goods across borders. Decomposing the ad valorem tax equivalent of trade costs between industrialized countries, Anderson and van Wincoop (2004) estimate that domestic distribution costs are more than twice as high as international transportation costs (55 versus 21 percent, respectively). Rousslang and To (1993) document that domestic freight costs on US imports are in the same order of magnitude as international freight costs. Using data on the cost of shipping a standard container from Baltimore to 64 destination cities around the world, Limao and Venables (2001) find that the per unit distance cost in the overland segment of the journey is significantly higher than in the sea leg. Moreover, these costs critically depend on the quality of the transportation infrastructure. Atkin and Donaldson (2014) estimate that intranational trade costs in

Ethiopia and Nigeria are 4 to 5 times larger than the estimates obtained for the United States. Consistent with this evidence, recent policy initiatives emphasize that an inadequate transportation infrastructure and inefficient logistics sector can severely impede developing countries' competitiveness (WTO 2004; WB 2009; ADBI 2009). For instance, the World Bank cites trade facilitation, which incorporates domestic transportation, as its "largest and most rapidly increasing trade-related work" as of 2013. Thus, quantifying the effect of internal transportation costs on international trade and understanding its channels are important for assessing trade-related benefits of transportation infrastructure investments.

As a case in point, Turkey increased the share of four-lane expressways in its interprovincial road stock from 11 to 35 percent between 2003 and 2012. The expansion of existing two-lane roads into divided four-lane expressways significantly improved the quality and capacity of roads while the total length remained essentially unchanged. Important for our study, these investments affected regions differently depending on where they were made, improving the connectivity of some regions to the international trade gateways of the country more than others. To exploit this variation, we use a rich dataset that provides information on province-level trade disaggregated by the international gateways of the country and estimate that the investment under study significantly reduced transport costs, and thus increased regional exports and imports. Using our baseline estimate, we calculate the cost of shipping over the mean distance in our data. Accordingly, the cost of an average-distance shipment drops by about 70 percent if the complete route is upgraded from a single carriageway to expressway. This result is robust to alternative specifications and instrumenting the change in route-specific road capacity with the initial capacity. Our estimates imply that the present value of a 10-year stream of trade flows generated by a one-dollar investment in road infrastructure ranges between \$0.7 and \$2. Finally, we show that transportation-intensive industries displayed higher trade growth in regions with above-average improvements in connectivity. This constitutes a plausible channel for the aggregate response of regional trade and strengthens our identification.

Recent work highlights the prevalence and importance of the issues that we explore. As noted above, Atkin and Donaldson (2014) estimate large internal trade costs in Ethiopia and Nigeria. Coşar and Fajgelbaum (2014) develop a model in which these costs lead to regional specialization in export-oriented industries close to ports, and verify this prediction in China. Allen and Arkolakis (2014) incorporate realistic topographical features of geography into a spatial model of trade and estimate the rate of return to the US Interstate Highway System. Focusing on historical episodes, Donaldson (2012) and Donaldson and Hornbeck (2013) analyze the welfare gains from railroads in India and the United States, respectively. We complement these studies by providing evidence on how a large-scale, capacity-enhancing public investment in transportation infrastructure in a developing country affects the volume and composition of its regions' international trade.

Our paper also contributes to a strand of literature that focuses on estimating the effect of transport infrastructure on trade and sectoral productivity. Using cross-country data, Limao and Venables (2001) and Yeaple and Golub (2007) find that infrastructure is an important determinant of trade costs, bilateral trade volumes, and comparative advantage.[1] Volpe Martincus and Blyde (2013) use the 2010 Chilean earthquake as a natural experiment to estimate the response of firm-level exports to the resulting geographical variation in access to ports. Volpe Martincus, Carballo, and Cusolito (2013) use historical routes in Peru to instrument for the location of new roads and find a sizeable impact on firm-level exports. A recent report by IADB (2013) explores the importance of domestic transportation infrastructure for regional exports in a number of Latin American countries. Albarran, Carrasco, and Holl (2013) find a positive impact of improved transportation infrastructure on small and medium-sized firms' probability of exporting in Spain. We complement these studies by proposing an alternative measure of road quality and an identification strategy for estimating its effect on trade. We also explore the importance of alternative channels

[1] Besides the length of roads, paved roads, and railways per sq km of country area, the infrastructure index used by Limao and Venables (2001) contains telephone main lines per person as well, making it impossible to tease out the isolated effect of the transportation infrastructure. In contrast, Yeaple and Golub (2007) investigate roads, telecom, and power infrastructure separately and find roads to have the biggest effect.

through which transportation infrastructure could exert its effects. To the extent that reducing internal transport costs helps developing countries participate in global supply chains in transportation-intensive industries, our results have important implications for industrial and commercial policies.

The next section introduces the background and the data. The results are presented in section 3.

2 Data and Preliminary Analysis

2.1 Background

Turkey is an upper-middle-income country (according to the World Bank classification) with a large population (78 million as of 2014) and a diversified economy. The country is the world's $17th$-largest economy, $22th$-largest exporter and $13th$-largest importer of merchandise goods by value (World Trade Report 2014, excluding intra-EU28 trade). It has been in a customs union for manufactured goods with the European Union since 1996, which accounts for more than half of the country's trade. Turkey is the fifth-largest exporter to the European Union and its seventh-largest importer.

Administratively, the country is divided into 81 contiguous provinces (*il* in Turkish) of varying geographic and economic size.[2] Each province is further composed of districts (*ilçe*). Some of these districts jointly form the provincial center (*il merkezi*), which is typically the largest concentration of urban population in a province. The top map in figure 1 outlines provincial boundaries and centers (see the notes to the figure).

Road transport is the primary mode of freight transport in Turkey. It accounts for about 90 percent of domestic freight (by tonne-km) and passenger traffic.[3] While the interprovincial road network has been extensive and paved, its capacity was considered quite inadequate

[2]Provinces correspond to the NUTS 3 (Nomenclature of Territorial Units for Statistics) level in the Eurostat classification of regions.

[3]See page 7 in GDH (2012). Data on modal shares by value are not available.

until recently. In order to relieve the congestion and reduce the high rate of road accidents, the authorities launched a large-scale public investment in 2002 in order to expand existing single carriageways (i.e., two-lane undivided roads) into dual carriageways (i.e., divided four-lane expressways). The investment was centrally planned and financed from the central government's budget with no direct involvement of local administrations.

As a result, the length of dual carriageways increased by more than threefold during the 2003-2012 period, while total road stock remained essentially unchanged (middle and bottom maps in figure 1, and figure 2). This capacity-expansion feature of the investment distinguishes the episode under study from the construction of new roads or the pavement of existing dirt roads, settings on which the related literature typically focuses (IADB, 2013).

External evidence suggests that the upgrades improved road transport quality in Turkey. Since 2007, the World Bank has been conducting a worldwide survey among logistics professionals every two years. The results are aggregated into the Logistics Performance Index (LPI), which ranges between 0 and 5; a higher LPI value indicates a more developed transportation sector as perceived by industry experts. In 2007, Turkey's score was 2.94, lower than the OECD average of 3.61. In 2012, Turkey's LPI value of 3.62 almost caught up with the OECD average of 3.68. Broken down into its components, the LPI covers the following six areas: customs, infrastructure, logistics competence, tracking and tracing, international shipments, and timeliness. In 2007, Turkey ranked $39th$ among 150 countries for the quality of trade- and transport-related infrastructure and $52nd$ for the timeliness of domestic shipments in reaching the destination. In 2012, Turkey scored higher on both indices; the country moved up 14 places in the infrastructure ranking, and 25 places in the timeliness ranking. On other indices, Turkey's rankings have not changed significantly: the country moved up one place in the customs ranking, four places in the logistics competence ranking, and five places in the tracking and tracing ranking. Consistent with reductions in shipping costs, Turkey's ranking in the international shipments index, which measures the ease of arranging competitively priced shipments, has also improved: the country moved up 11 places between

2007 and 2012. Furthermore, according to the Global Competitiveness Report (World Economic Forum) rankings based on the quality of road infrastructure, Turkey moved up 10 places to 43*th* among 148 countries between 2006-2012.[4]

We finish this subsection by noting that the objectives of the investment program alleviate concerns related to the selection of provinces for foreign trade-related outcomes. Policy documents explicitly state that the goal was "to ensure the integrity of the national network and address capacity constraints that lead to road traffic accidents."(GDH 2014). The long-term goal is to improve connections between all provincial centers to form a comprehensive grid network spanning the country, rather than boosting the international trade from particular regions. Against this backdrop, we will further address endogeneity concerns in our empirical investigation.

2.2 Data

Data on province-level manufacturing exports and imports for the 2003-2012 period are provided by the Turkish Statistical Institute (TUIK). An important aspect of these flows for our purposes is the gateway g through which trade occurs. 20 out of 81 provinces are gateway provinces, hosting either a seaport or a border crossing. We observe annual trade flows between each province-gateway pair: $trade^f_{pgt}$ denotes export or import flow $f = \{exp, imp\}$ of province p through gateway g at year t, denominated in current year USD.

Trade flows are further disaggregated by partner country and 22 manufacturing industries (in 2 digit ISIC Rev.3 classification). For confidentiality reasons, TUIK does not disclose the data at the province-gateway-country-industry-year ($pgcit$) level since individual firms may be detected at this level of detail. We thus work with trade data at the province-gateway-year (pgt), province-gateway-country-year ($pgct$) and province-gateway-industry-year ($pgit$)

[4] The ranking is constructed based on a survey question that asks respondents to rate the quality of roads in their countries from 1 ("extremely underdeveloped") to 7 ("extensive and efficient—among the best in the world"). Turkey improved its score from 3.72 in 2006-2007 to 4.87 in 2012-2013. Demir (2011) also uses quality indices published by the World Economic Forum and reports that the elasticity of Turkey's trade with respect to the quality of its overall transport infrastructure is around unity.

levels, depending on the specification.

Table 1 summarizes key descriptive trade statistics. As the top panel shows, exports and imports both increased substantially between 2003 and 2012, regardless of the unit of observation. The middle panel shows the extensive margins of this increase. The number of gateways through which provinces trade, the number of countries they trade with and the number of industries they trade in all display sizable increases from 2003 to 2012. These patterns suggest that the expansion of road capacity between 2003-2012 may have affected regional trade on extensive as well as intensive margins.[5]

Data on the stock and composition of roads at the province level are provided by the Turkish General Directorate of Highways. To be precise, our data inform us about the total length of all roads ($roadStock_{pt}$) and expressways ($expressway_{pt}$) within provincial boundaries at each year between 2003-2012. By definition, $expressway_{pt} \leq roadStock_{pt}$, which holds with strict inequality for all province-year observations.

Several remarks are in order. The road data are available at a level of aggregation that does *not* inform us about particular segments between nodes. Neither do we have geographical information about the network. Figure 3 helps to illustrate this. The three tiles here represent three provinces, their centers and boundaries. At any given year, the network is composed of single carriage roads (red lines) and expressways (black lines). We only know the total length of these roads within provincial boundaries, rather than whether there is an expressway connecting the centers (P_1, P_2, G). Since trade data come at the same level of aggregation, with exporters/importers spread within provinces' boundaries, the lack of geographical detail on roads does not strike us as critical.

For our empirical analysis, however, we need a measure of provincial access to gateways.

[5] Since our empirical analysis will exploit trade flows at the province-gateway level, it is important to note that it is *not* just the nearest gateway that matters for a province's foreign trade. Ports and border crossings are specialized in industries and trade partners: an overwhelming majority of trade in a certain industry with a certain country goes through a single port. This specialization is consistent with both geography—the border crossing to Syria is irrelevant for trade with Germany—and logistics technology—there are strong increasing returns at ports due to containerization and industry-specific port equipment. With this in mind, it is important to consider all existing or newly formed pg links during our data period.

We obtained shortest road distances $dist_{pg}$ and the associated routes J_{pg} between provincial centers from Google Maps. J_{pg} is the set of provinces one has to traverse on the shortest distance route between p and g, including the origin and the destination. In figure 3, $J_{P_1,G} = (P_1, P_2, G)$ and $dist_{P_1,G}$ is the length of the road connecting P_1 and G through P_2.

In order to calculate pg-level improvements in road capacity over time, we calculate the *expressway road share* on the shortest distance route J_{pg} at year t:[6]

$$ers_{pgt} = \frac{\sum_{j \in J_{pg}} expressway_{jt}}{\sum_{j \in J_{pg}} roadStock_{j,2003}}.$$

The bottom panel of table 1 shows summary statistics for this variable over time (an increase from 9.1 percent in 2003 to 31.1 percent in 2012), as well as for time invariant pg distances.

In what follows, we propose to identify the effect of road capacity on trade through the period change in expressway road share:

$$\Delta ers_{pg} = ers_{pg,2012} - ers_{pg,2003},$$

which shows considerable variation without clustering in certain regions of the country (figure 4) and suggests that province-gateway pairs with poor initial connections experienced larger improvements (figure 5).

2.3 Preliminary Analysis

Before moving on to the main empirical analysis, we note that for the purpose of estimating the transport-cost reducing impact of expressways, it would have been ideal to also have data on domestic trade between cities. Such information, however, is typically not available

[6] We fix the denominator, the length of total road stock, in its 2003 value. Additions to the road network are quantitatively small over this time period (see figure 2), and more importantly, all upgrades were done on single carriageways that were in operation as of 2003. For the same reason, and also because we do not have access to previous years' maps, we use the shortest distance route J_{pg} as obtained from Google Maps in 2013 for the entire data period. The results are robust to using yearly values for the denominator, which shows slight variation.

for developing countries. Observing the domestic components of export/import shipments thus provides us with limited but useful information to estimate how such flows are generally affected by transport infrastructure. With 20 gateway provinces as "origins" of imports to 81 provinces and as "destinations" of exports from provinces, our data can be fit with a simple gravity model, which is a standard tool for explaining bilateral trade flows:

$$\ln trade^f_{pg} \;=\; \delta^f_p \;+\; \delta^f_g \;+\; \gamma \ln dist_{pg} \;+\; \epsilon_{pg}, \tag{1}$$

where (δ^f_p, δ^f_g) are gateway- and province-flow fixed effects, reminiscent of exporter and importer fixed effects in international gravity estimations.

Table 2 reports the results. We estimate the distance elasticity of flows separately at the beginning (2003/04) and at the end (2011/12) of the period under consideration. Excluding own-shipments for $p = g$ with $dist = 0$, i.e. exports and imports of gateway provinces through their own ports, there are $3,200$ possible flows in our data ($= 81 \times 20 \times 2 - 20 \times 2$). The OLS estimates in the first two columns use positive flows only. The much higher number of observations in the 2011/12 sample is a manifestation of the extensive margin increase documented in table 1.

Given the pervasiveness of zero flows and the well-known problems associated with using OLS to estimate gravity models (Santos-Silva and Tenreyro, 2006), we also use a Poisson pseudo-maximum likelihood (PPML) estimator in third and fourth columns.[7] Consistent with the well-documented pattern in the literature, our PPML estimates of distance elasticity are smaller in absolute value than the respective OLS estimates. The estimates are in the range of elasticities reported by Head and Mayer (2014). Comparing the 2003/04 and 2011/12 sample, we see that the elasticity estimated for the latter period is smaller in absolute value: a one percent increase in distance decreases trade by 1.4 and 1.2 percent in the beginning versus the end of the period, respectively.

[7] Number of observations in these columns falls short of 3,200 because the PPML routine drops exporters (importer) with no positive trade flows with any partner in the presence of exporter (importer) fixed effects.

This drop motivates us to further investigate the relationship between road capacity improvements and changes in trade outcomes over time. To this end, figure 6 plots the residual period change in trade for provinces against a proxy that captures their improvement in accessing foreign markets. In particular, we sum export and import flows ($trade_{pg} = \Sigma_f trade^f_{pg}$), and fix the initial share of each gateway in a province's trade ($\pi_{pg} = trade_{pg}/\Sigma_g trade_{pg}$). We then regress $\Delta \ln trade_{pg}$ on province and gateway fixed effects, and plot in the y-axis the average residuals using π_{pg} as weights. This captures the average period change in trade for a province, after adjusting for its own average and the average of the gateways it trades through. The x-axis is simply $\Sigma_g \pi_{pg} \Delta ers_{pg}$, i.e., the average improvement in a province's access to its gateways, using the same trade shares as weights. The slope of the regression line plotted in the figure is 2.997 with a p-value of 0.6. The following section provides a more thorough examination using a rich set of controls and an instrument for road capacity expansions.

3 Empirical Analysis

To derive our estimating equation, we specify bilateral trade flows between province p and gateway g in a general gravity setting:

$$trade^f_{pgt} \ = \ \omega^f_{pt} \cdot \omega^f_{gt} \cdot TC^{-\theta}_{pgt}, \tag{2}$$

where ω^f_{pt} captures time-varying province-level variables that affect its exports/imports, and ω^f_{gt} captures time-varying factors that affect international demand and supply through gate g (such as income in destination countries that can be reached through g). TC_{pgt} is the cost of transportation and $\theta > 0$ denotes the elasticity of trade flows with respect to transportation costs.[8]

We assume that the cost of transportation at time t is a function of the distance and the quality of roads connecting the pg pair:

$$TC_{pgt} \;=\; dist_{pg}^{\tau_e \cdot ers_{pgt} \,+\, \tau_s \cdot (1-ers_{pgt})}, \tag{3}$$

where τ_e, τ_s are positive distance elasticities associated with new expressways and old single-carriageway roads, respectively. Taking the logarithm of (3) and defining $\tau = \tau_s - \tau_e$,

$$\ln TC_{pgt} \;=\; \tau(1 - ers_{pgt}) \ln dist_{pg} + \tau_e \ln dist_{pg}. \tag{4}$$

In our setting, time-variation in transport costs is driven by changes in ers_{pgt} over time, captured by the first term. We obtain the following specification by taking the logarithm of both sides in (2) and replacing $\ln TC_{pgt}$ with (4):

$$\ln trade^f_{pgt} \;=\; \ln \omega^f_{pt} + \ln \omega^f_{gt} - \theta\tau(1 - ers_{pgt}) \ln dist_{pg} - \theta\tau_e \ln dist_{pg}. \tag{5}$$

To gauge the long-term effect of increasing ers_{pgt} on trade flows, we take the time difference as

$$\Delta \ln trade^f_{pg} \;=\; \Delta \ln \omega^f_p \;+\; \Delta \ln \omega^f_g \;-\; \theta \cdot \underbrace{\tau \left[\Delta(1 - ers_{pg})\right] \ln dist_{pg}}_{= \Delta \ln TC_{pg}}, \tag{6}$$

where $\Delta x = x_{2012} - x_{2003}$ denotes the difference between 2012 and 2003 levels of a variable. Note that the time-invariant term $\tau_e \ln dist_{pg}$ in transport costs (5) drops when taking the difference. If the cost of transport on expressways increases with distance at a smaller rate than it does on single carriageways, i.e., if $\tau_s > \tau_e \Rightarrow \tau > 0$, an increase in ers will reduce TC and increase trade in (6). We are now ready to test this relationship.

[8]Since our motivation is to estimate transportation costs, we start directly with a general gravity equation and do not take a stand on the underlying source of trade. As summarized by Head and Mayer (2014), various workhorse models of trade comply with this general gravity specification while the structural interpretation of the trade elasticity θ varies across models (Arkolakis, Costinot, and Rodriguez-Clare, 2012).

3.1 Road Capacity and Trade

Replacing $\Delta(1-ers_{pg}) = -\Delta ers_{pg}$ in the gravity-based equation (6) leads us to the following estimating equation:

$$\Delta \ln trade^{f}_{pg} \;=\; \delta^{f}_{p} \;+\; \delta^{f}_{g} \;+\; \beta \cdot \underbrace{\Delta ers_{pg} \cdot \ln dist_{pg}}_{=\,\Delta RC_{pg}} + \epsilon_{pg}, \tag{7}$$

where $\beta = \theta\tau$. Gateway- and province-flow fixed effects $(\delta^{f}_{p}, \delta^{f}_{g})$ simply relabel $[\Delta \ln \omega^{f}_{p}, \Delta \ln \omega^{f}_{g}]$ in (6). For convenience, we denote the explanatory variable as the change in *road capacity*, $\Delta RC_{pg} = \Delta ers_{pg} \ln dist_{pg}$. Since $\Delta ers_{pg} > 0$ for all pg pairs, we expect β to be positive: an increase in road capacity (and the corresponding decrease in transport costs) will increase trade.

While (7) identifies β, the underlying structural parameter of interest τ cannot be separately identified from the elasticity θ of trade flows to trade costs, as it is standard in the gravity literature (Anderson and van Wincoop, 2004). In what follows, we present β coefficients estimated from various specifications of (7) and use $\theta = 4$ based on Simonovska and Waugh (2013) to calculate τ using the delta method. In various specifications below, we also control for the direct effect of Δers.

Table 3 presents the first set of results starting with OLS estimates. The individual effect of Δers in column 1 extends the analysis in figure 6 above and confirms its robustness in a finer level of aggregation. The OLS estimate of the coefficient on the variable of interest, ΔRC_{pg} in column 2 is significant at the 1% level. In column 3, we add Δers as an additional control. The estimate of β retains its significance with a slight change in magnitude.

The specification presented in column 3 of table 3 implies an estimate for τ that equals 0.186 with a standard error of 0.051.[9] To give a sense of the transport cost reduction, take

[9] Since θ is an estimate itself, we calculate the expected value and the standard error of τ using the multivariate extension of the delta method. In particular, $E(\tau) = E(\beta/\theta) \approx \mu_\beta/\mu_\theta$ and $Var(\tau) \approx (\mu_\beta/\mu_\theta)^2(Var_\beta/\mu^2_\beta + Var_\theta/\mu^2_\theta - 2Cov(\beta,\theta)/(\mu_\beta\mu_\theta))$. We take the mean and the variance of β from 100 random samples of size 750. Using $(\mu_\theta = 4.1, Var_\theta = 0.0081)$ from table 5 of Simonovska and Waugh (2013), and assuming $Cov(\beta,\theta) = 0$, we impute $E(\tau) = 0.186$ and $Var(\tau) = 0.051^2$.

the PPML estimate from 2003-2004 (column 3 of table 2) as $\tau_s = 1.384$, as expressway road shares were very low at the beginning of our sample—i.e., while $ers > 0$ for most of the routes in these initial years, we round it down to zero for the sake of this back-of-the-envelope calculation. This implies $\tau_e = \tau_s - 0.186 = 1.198$. We use these elasticities in the transport cost function (3) to calculate the cost of shipping over the mean pg distance of 820 km in our data when the road covering that distance is single carriageway versus expressway. We find that the cost of an average-distance shipment drops by 70 percent if the complete route is upgraded from a single carriageway, i.e., from $ers = 0$ to $ers = 1$. This is a substantial drop in transport costs.[10]

To further quantify the effect, we calculate that each dollar spent on quality-improving investment in transport infrastructure generates a 10-year discounted stream of trade flows between \$0.7 and \$2. The calculation is based on the specification presented in column 3 of table 3. We consider a hypothetical route with the mean distance (820 km) in the data. To reduce transport costs by 1 percent on this route, an additional 6.57 km of roads have to be transformed into divided roads.[11] We calculate the average cost of building 6.57 km of a four-lane road over the 2003-2012 period.[12] Next, we use the estimated elasticity of τ based on the specification presented in column 3 of table 3 to calculate the value of trade flows (at the mean) generated by a 1 percent decrease in transport costs. For discount factors between 0.15 and 0.05, the present value of a 10-year stream of trade flows generated by a one-dollar investment in road infrastructure ranges between \$0.7 and \$2.[13]

On overall, our results imply a sizeable effect of road capacity expansion on regional trade. There are several mechanisms through which the investment alleviated the negative impact

[10]In the TC function, we set $dist = 820$. Initially the share of expressways is zero, $ers = 0$, and the corresponding value of TC is $dist^{\tau_s} = 10,782$; and for $ers = 1$, it is $dist^{\tau_e} = 3,095$.

[11]Given equation (3), the amount of road expansion (in km) needed to decrease transport costs by 1 percent is given by: $\frac{0.01*820}{\tau \ln \overline{dist_{pg}}}$.

[12]The average cost of building a 1 km of a four-lane road is \$1.1 million over this period (Directorate of Strategy Development of the Ministry of Finance, 2011, "POLİTİKA ANALİZİ: ULAŞTIRMA SEKTÖRÜ BÖLÜNMÜŞ YOL ÇALIŞMASI)." The report is available from the authors upon request.

[13]Note that this calculation does not reflect the rate of return to investment since it does not take into account within-country trade. Doing so, Allen and Arkolakis (2014) estimate a rate of return for the US Interstate Highway System around 100 percent.

of remoteness. Reduced congestion on main arteries implies a higher cruising speed for the vehicles on the road. Increased road capacity can also be associated with the observed fall in accidents: traffic-related fatalities per vehicle-km decreased by 40 percent from 2004 to 2011. A direct benefit of reduced accident rates is a possible reduction in freight insurance costs. Average cruising speed may also increase due to a lower probability of a road closure following an accident. All these benefits are likely to improve the timeliness and predictability of deliveries. Better road quality may also reduce transportation costs through reduced maintenance and depreciation costs in the logistics sector.

Instrumental Variable Estimation: We documented that the primary motivation behind the investment program was to relieve congestion and reduce the high rate of road accidents, which partly alleviates endogeneity concerns. Also, first-differencing implicitly controls for any time-invariant pg level factors that might be correlated with the error term. Still, under a less likely scenario, policy-makers could favor some routes over others, for instance because there already existed strong exporters located in p trying to reach a particular gateway g. To address such concerns, we estimate an instrumental variable model, using the initial share of expressways along pg routes as an instrument. In doing so, we follow the literature estimating the impact of trade liberalization using as instrument initial tariff levels, (e.g. Goldberg and Pavcnik 2005; Amiti and Konings 2007; Topalova 2010). The following facts suggest that initial expressway share ($ers_{pg,2003}$) is a valid and informative instrument for its change over the period under consideration. The public investment program aimed at "upgrading into expressways all the roads connecting the country to international markets and those connecting provincial centers."[14] If fully achieved, upgrading all roads would bring all pairs into the same level, i.e., equal to one. While incomplete as of 2012, the investment program led to noticeable convergence in the share of expressways across pg routes. This is confirmed by a substantial fall in its dispersion: the coefficient of variation fell from 0.34

[14] See the bottom bullet point in page 55 of the policy document "TÜRKİYE ULAŞIM VE İLETİŞİM STRATEJİSİ-HEDEF 2023" published by the Ministry of Transport, Maritime and Communications of the Republic of Turkey, available at http://www.izmiriplanliyorum.org/static/upload/file/turkiye_2023_ulasim_ve_iletisim_stratejisi.pdf.

in 2003 to 0.13 in 2012 (bottom panel of table 1). For our purposes, the initial share of expressways becomes a good predictor of its change over this period. As illustrated in figure 5, there is a strong negative association between the initial share of expressways and its period change. A coefficient of -0.6 shows the degree of this catch-up.

We thus estimate (7) using a two-stage least squares model that instruments ΔRC_{pg} in the following first stage:

$$\Delta RC_{pg} = \gamma_p + \gamma_g + \alpha_1 (ers_{pg,2003} - 1) \ln dist_{pg} + \alpha_2 \ln dist_{pg} + \eta_{pg}. \tag{8}$$

First-stage results are presented in column 5 of table 3. Since the instrument is the initial level of log transport costs, the term $\ln dist_{pg}$ does not drop out in the first stage.[15] The value of the Kleibergen-Paap F-statistic is high, suggesting that our IV estimates are not likely to suffer from bias due to weak instruments. Columns 6 and 7 present the estimation results from the second-stage. The estimated coefficients on ΔRC_{pg} are still significant at the 5% and 10% levels.[16] While the IV estimates in columns (6)-(7) are slightly larger than the OLS estimates in columns (2)-(3), Durbin-Wu-Hausman test suggests that the OLS estimate is consistent at any conventional significance level.

Finally, to strengthen our argument about the validity of the instrument, we test the robustness of our results to deviations from the assumption of perfect exogeneity. To do so, we follow the method proposed by Conley, Hansen, and Rossi (2012) and convincingly applied by Nunn and Wantchekon (2011). The test relaxes the assumption of perfect exogeneity and assumes a flexible second-stage regression that also includes the instrument as a regressor. If the coefficient on the instrument in the second-stage regression is known, one can obtain consistent estimates of the effect of ΔRC_{pg} on the dependent variable. To implement this

[15] More precisely, we are essentially instrumenting $\Delta\big[\tau(1 - ers_{pg}) \ln dist_{pg} + \tau_e \ln dist_{pg}\big]$, the change in (log) transport costs, with its 2003 level. The instrumented variable $\Delta RC_{pg} = \Delta ers_{pg} \ln dist_{pg}$ in the estimating equation (7) simply follows from cancelling the time-invariant term $\tau_e \ln dist_{pg}$ by differencing, reversing the sign by $\Delta(1 - ers_{pg}) = -\Delta ers_{pg}$ and absorbing τ in $\beta = \theta\tau$.

[16] A similar back-of-the-envelope calculation using the estimate of τ from column 6 implies that transforming all single carriage roads into expressways reduces the cost of shipping over the mean pg distance in our data by 75 percent.

method in our setting, we need a consistent estimate of the direct effect of the initial level of transport costs along a pg route on the change in bilateral trade flows. For the estimation of this direct effect, we exploit the fact that only a tiny share of roads was converted into expressways in the first year of the investment period.[17] Given that ΔRC_{pg} is close to zero between 2003-2004, we can estimate the following equation for 2003-2004:

$$\Delta trade_{pg}^{f} = \delta_p^f + \delta_g^f + \alpha(ers_{pg,2003} - 1)\ln(dist_{pg}) + \epsilon_{pg}^f.$$

The coefficient on $(ers_{pg,2003} - 1)\ln(dist_{pg})$ is estimated to be positive (0.07) but insignificant. If we assume that α varies on the interval $[0, 0.07]$, there is 90% probability that our coefficient of interest β would vary between $[0.34, 1.86]$. Indeed, any positive value of α would imply a positive estimate for β, with estimates increasing in the value of α. This exercise shows that our earlier findings are robust to relaxing the assumption of strict instrument exogeneity.

Additional Controls and Alternative Specifications: Table 4 checks the robustness of results to the inclusion of relevant controls. Column 1 directly includes the initial level of ers and its interaction with log distance as independent variables instead of using them as instruments. In column 2, we add distance as an additional control to the baseline specification to check whether flows at longer distances (above median) have different trends than those at shorter distances (below median). The coefficient on above-median distance dummy is estimated to be insignificant while our coefficient of interest retains its significance. Columns 3 controls for the period change in per capita income in each pg route.[18] The next column adds the change in total trade flows over the 1996-2001 period in each pg route and its interaction with distance. Controlling for trade change prior to the investment period addresses the concern that some routes may have been selected for their past trade performance or the routes

[17] In particular, the 99th percentile of the change in the share of expressways between 2003-2004 (0.06) is almost half of the first percentile of its cumulative change over the entire period (0.11). We still restrict the sample to pg pairs with an annual increase below 0.02, which corresponds to the 10th percentile of the distribution of Δers_{pg}^{03-04}.

[18] Province-level income data have not been published in Turkey since 2002. The only available data start from 2004 and are at the NUTS2 level.

receiving above average investment may have been on a spurious upward trend. Column 5 adds as controls the fixed effects estimated from the baseline gravity specification (2) in table 2 and their interaction with log distance to proxy for market and supplier access as in Redding and Venables (2004). While there is some variation in point estimates, the qualitative results largely survive these checks.

We also subject the analysis to alternative specifications and report the IV results in table 5. In column 1, we exclude origin and destination provinces from the construction of expressway road shares and define the "between" measure as $\Delta ers_{pg}^{bw} = \frac{\sum_{j \in J_{pg} \& j \neq \{p,g\}} \Delta expressway_j}{\sum_{j \in J_{pg} \& j \neq \{p,g\}} roadStock_{j,2003}}$. The result shows that the explanatory power comes from in-between provinces alone.

In columns 2 and 3, we replace the trade cost function (3) with alternative specifications. We first let

$$TC_{pgt} = \exp\left(\tau_e \cdot [ers_{pgt} dist_{pg}] + \tau_s \cdot [(1 - ers_{pgt}) dist_{pg}]\right).$$

Making the appropriate substitutions, taking natural logarithms and long-differences yields a semi-elasticity specification where the independent variable is $\Delta ers_{pg} \times dist_{pg}$. While the coefficient in column 2 is no longer comparable to the baseline, the estimate is of the right sign and significant at the 5% level.

We then let trade costs be a function of travel times: $TC_{pgt} = \exp(\gamma \cdot time_{pgt})$. Given (v_s, v_e), the velocity of trucks on single carriageways and expressways, travel time between p and g is

$$time_{pg} = \frac{ers_{pg} dist_{pg}}{v_e} + \frac{(1 - ers_{pg}) dist_{pg}}{v_s}.$$

Repeating the algebra, we get

$$\Delta \ln TC_{pg} = \gamma \Delta time_{pg} = \gamma \left[\Delta ers_{pg} \cdot dist_{pg} \left(\frac{1}{v_e} - \frac{1}{v_s} \right) \right].$$

Substituting this into (6) allows us to identify $\theta\gamma$ from time variation in ers. Thus, the gains from the road investment in this case directly accrue from reduced travel times on expressways.[19] The estimate in the third column of table 5, instrumenting $\Delta \ln TC_{pg}$ with $time_{pg}^{2003}$, implies $\gamma = 0.522$ and a reduction of travel costs around 27 percent on an average stretch of 820 km upon upgrading.

We documented the establishment of new trade links between pg pairs over time in table 1. To incorporate this extensive margin improvement into our analysis, we define the dependent variable as $2 \cdot (trade^{f}_{pg,2012} - trade^{f}_{pg,2003})/(trade^{f}_{pg,2012} + trade^{f}_{pg,2003})$ and report the IV estimate in the $4th$ column of table 5. Ranging between -2 and 2, this measure incorporates all pg pairs that have a trade relationship in 2003 or 2012. As a result, the sample size increases from 1015 observations to 1687. The estimate has the expected sign and is significant at the 1% level.

In order to investigate further whether the baseline estimates are subject to selection bias arising from the fact that they are based on a sample of pg pairs that have always traded with each other over the 2003-2012 period, we follow the approach suggested by Mulligan and Rubinstein (2008) and report the results in table 6. We first estimate the probability of observing positive trade for a pg pair in both 2003 and 2012, and obtain predicted selection probabilities. We then estimate equation (7), also controlling for Δers_{pg}, on subsamples determined by the predicted selection probabilities, i.e. subsamples of pg pairs with the predicted probabilities above certain percentiles of the selection probability distribution. If our intensive margin estimates are not subject to serious selection bias, then estimates obtained from different subsamples should be close to the one obtained from the whole sample. First column of table 6 shows that, after controlling for province and gateway fixed effects, the initial volume of bilateral trade flows is the only statistically significant determinant of the probability of observing positive trade for a pg pair in both years.[20] Column 2 replicates the baseline IV estimation presented in column 7 of table 3. Columns

[19] We use the official speed limits for expressways and single carriageways in Turkey ($v_e = 85$ km/hour and $v_s = 80$ km/hour, obtained from the following website on September 2015: http://www.kgm.gov.tr/Sayfalar/KGM/SiteTr/Trafik/HizSinirlari.aspx).

[20] Number of observations drops in the first column of table 6 because some fixed effects predict failure or success perfectly.

3 to 6 show the results obtained from the estimation of equation (7) on subsamples of pg pairs with the predicted probabilities above the $10th$, $25th$, $50th$ and $60th$ percentiles of the selection distribution. The coefficient estimates are not statistically different from the one presented in column 2. A generalized Hausman test of the hypothesis that difference in coefficients between columns 3-6 is zero gives a value of 2.340, with an associated p-value of 0.505. We thus conclude that our estimate of the intensive margin elasticity of trade flows with respect to road capacity is not subject to serious selection bias.[21]

Extensive Margin: To further investigate the effect of road capacity improvements in the initiation of new trade flows through gateways, we estimate a linear probability model in which we replace the dependent variable in equation (7) with a binary variable New^f_{pg} that takes the value one if a new province-gateway trade link has started, i.e., $trade^f_{pg}$ turns from zero in 2003 to positive in 2012, and zero otherwise. Table 7 presents the results.[22] According to our IV estimate (column 1), a one percent increase in road capacity increases the probability of a new trade link by 0.088. The estimated value of the coefficient increases slightly when the period change in the share of expressways is controlled for (column 2). The result is robust to using the between-provinces measure in column 3 and adding additional controls in columns 4-6.

Given the specialization of ports in industries and in partner countries, a new pg link implies that province p trades with new partners in new industries. We now look into these margins of the observed trade expansion at the pg-level, namely the country (trade partner) and industry dimensions of our data. We decompose pg-level trade into the number of

[21]As an additional robustness check, we use the generalized propensity score (GPS) method developed by Hirano and Imbens (2004), which is an extension of the standard PS approach to cases with continuous treatment. Results show that the level of treatment (ΔRC_{pg}) is significantly associated with only the initial share of expressways along the route, ers^{2003}_{pg}. The fact that other pre-treatment variables do not significantly explain ΔRC_{pg} supports the hypothesis that our instrument is valid. The estimated dose-response function and the corresponding 95% confidence bands show that the marginal effect of ΔRC_{pg} on pg-level trade is highly significant and varies around one – which is consistent with the estimate of β we obtain from the baseline OLS/IV regressions in table 3. This exercise provides an external validity check of the OLS/IV analysis. GPS results are available from the authors on request.

[22]Probit and IVProbit estimates are qualitatively and quantitatively similar to LPM and IVLPM estimates. The reason we report the latter is that linear models provide a more flexible approach in the presence of many fixed effects. Probit and IVProbit results are available from the authors.

countries or industries traded, and the average volume of trade per *pgc* or *pgi*. We estimate equation (7) for both margins and present the results in table 8. Columns 1 and 4 replicate the baseline IV results in column 7 of table 3, while columns 2-3 and 5-6 feature the intensive-extensive margin decompositions. For both dimensions, the intensive margin is insignificant despite having the right sign. In the extensive margin, *pgc*-level effects are significant (column 3) at the 10% level. Around one-third of the overall trade increase is due to the extensive margin (0.286/0.858), i.e., establishment of links with new trade partners. The extensive margin is also significant at the industry dimension, and it accounts for about 87 percent of the trade increase (0.757/0.858). By identifying the channels in terms of industries and destination/source countries, these results complement the finding that improvements in road capacity were associated with increased trade within *pg* pairs.

We finish this subsection by asking whether intensive and extensive margin results differ when estimated for imports and exports separately, rather than using the pooled sample as we did so far.[23] Table 9 shows that for imports, it is the intensive margin that matters while for exports, the extensive margin of reaching new ports is the key driver.

3.2 Road Capacity and Transportation Intensive Industries

Having documented the trade-enhancing effect of expressway construction, we now explore a potential channel through which this increase may have materialized. One would expect that the more transportation-intensive an industry is, the greater the impact of improved road capacity on its trade would be. This may be due to two industry characteristics: sensitivity to the length and precision of delivery times, and the heaviness of it inputs or outputs.

For some agricultural goods, time-sensitivity may arise simply due to perishability. The literature recognizes other causes as well: for intermediate goods that are part of international supply chains, timeliness and predictability of delivery times are crucial. Industries with volatile demand for customized products display high demand for fast and frequent

[23] To be able to make comparisons across flows, we restrict the sample to *pg* pairs for which we observe both trade flows in the data.

shipments of small volumes (Evans and Harrigan 2005). Time-in-transit also constitutes a direct inventory-holding cost itself. Using data on US imports disaggregated by mode of transportation, Hummels and Schaur (2013) exploit the variation in the premium paid for air shipping and in time lags for ocean transit to identify the consumer's valuation of time. They estimate an ad valorem tariff of 0.6-2.3 percent for each day in transit.

In our setting, one of the components of the domestic LPI (described in section 2) is "export lead time," which measures the time it takes to transport goods from the point of origin to ports. The LPI data show that the median export lead time in Turkey decreased from 2.5 days in 2007 to 2 days in 2012, marking an improvement relative to the best performer (Singapore). Considering time as a trade cost, such evidence further motivates us to test the hypothesis that capacity-enhancing investment in road infrastructure in Turkey contributed relatively more to increased regional foreign trade in time-sensitive industries during the 2003-2012 period.

Heaviness is another determinant of how transportation intensive an industry is. Duranton, Morrow, and Turner (2013) estimate the effect of the US highway system on the value and composition of trade between US cities, and find that cities with more highways specialize in sectors producing heavy goods.

Guided by the empirical literature investigating the mode of shipping decisions, we define two industry-level variables, Air_i and $Heavy_i$, to capture characteristics that are related to transport intensity of goods:

$$Air_i = \frac{air\_val_i}{air\_val_i + ves\_val_i} \quad , \quad Heavy_i = \ln\left(\frac{ves\_wgt_i}{ves\_val_i}\right) \tag{9}$$

where air_val_i denotes the value of trade by air for a country, and ves_val_i (ves_wgt_i) the value (weight) of trade by ocean vessel. In order to capture industry characteristics in a setting that is exogenous to shipping decisions in Turkish trade, we use industry-level imports into the United Kingdom in 2005. Table 10 reports the values for both variables.

As expected, the correlation coefficient between the two is strongly negative (-0.54)—air shipping is less suitable for goods with a high weight-to-value ratio (Harrigan 2010). Beyond being of interest in and of itself, heaviness of an industry thus serves as an important control for air share to be a good proxy for time-sensitivity.

Our next specification interacts these variables with the change in road capacity:

$$\Delta \ln trade^f_{pgi} = \delta^f_{pg} + \alpha \cdot \Delta RC_{pg} \times \theta_i + \gamma_a \cdot \Delta RC_{pg} \times Air_i + \gamma_h \cdot \Delta RC_{pg} \times Heavy_i + \epsilon_{pgi}, \quad (10)$$

where θ_i controls for potential differences in demand elasticities across industries. Here long-term differencing eliminates industry fixed effects which may be driving air shares for reasons other than the time-sensitivity of industries. If provinces with a higher increase in road capacity experienced a larger increase in the trade of time-sensitive and heavy goods, the coefficients γ_a and γ_h will be positive.

An important factor to consider in this exercise is that a systematic relationship between industries' demand elasticities and their heaviness/air shares will bias the estimates of γ_a and γ_h. To address this concern, we control in equation (10) for the interaction between road capacity changes and industry-level elasticity of substitution θ_i estimated using the Broda and Weinstein (2006) methodology. [24]

Results are presented in table 11. All specifications use the instrumental variable method and cluster standard errors at the province-gateway level. We also control for additional interactions such as $\Delta ers_{pg} \times Air_i$. To make coefficient interpretation easier, we redefine Air_i and $Heavy_i$ as binary variables, indicating whether their values lie above their respective medians. Air share and heaviness have the expected signs and are significant at the 10% and 5% levels, respectively (column 1). Controlling for demand elasticities in the second column does not change the magnitude and significance of either variable, and we fail to find

[24] In models that feature CES preferences, the elasticity of substitution governs the price elasticity of demand and trade elasticity (Arkolakis, Costinot, and Rodriguez-Clare, 2012): a higher θ_i implies greater elasticity of trade to transport costs. We use elasticities at the HS10 level estimated by Soderbery (2015) and map it into our industry aggregation at the ISIC Rev.3 2 digit level.

evidence that industries with higher elasticity benefited more from transport cost reductions.

In columns 3 and 4 of table 11, we test whether fall in transport costs, caused by road capacity enhancements, increased the probability that pg pairs start trading in transport-sensitive industries. To do so, we estimate an equation similar to equation (10) replacing the dependent variable with a binary variable that takes on the value one if a pg pair trading in industry i in the post-investment period did not do so in the pre-investment period, and zero otherwise. Since this equation is not estimated in differences, we also control for industry fixed effects. Results show that time sensitivity as captured by air shares matters for the initiation of trade in response to road quality improvements.

To understand the economic significance of our estimates, let us work through an example. Consider two routes at the $90th$ and $10th$ percentiles of expressway road share increase (Δers). We ask how, at the median distance and for below-median heaviness, the trade responses of these two routes to a one percent increase in road capacity differ between two industries with above- and below-median air shares. Using the estimates from the first column of table 11, we find an economically significant effect: the difference in trade increase is 50 percentage points.[25]

The stronger response in sectors that are expected to be more sensitive to road quality adds credibility to the claim that we are identifying the effect of reductions in transportation costs on trade. While we argued that endogenous selection is not a major concern in our setting, this claim is even stronger for the evidence presented here. It is very unlikely that planners prioritize investments in a province because of anticipated trade growth in certain products.

[25] Precisely, we calculate a double difference by evaluating the relative change in trade between industries with above- and below-median air shares for two routes with $\Delta ers = 0.27$ and $\Delta ers = 0.17$, corresponding to the $90th$ and $10th$ percentiles. Taking the median distance ($dist = 775km$) and $Heavy = 0$, trade in an industry with above-median air-share doubles while trade in an industry with below-median air-share increases by 50 percent.

4 Conclusion

This study investigates the effect of Turkey's large-scale investment in the quality and capacity of its road transportation network on the level and composition of international trade associated with subnational regions within Turkey. Transport cost reductions brought about by this investment led to increased trade with regions whose connectivity to the international gateways of the country improved most, the main channels being the increases in the extensive margins of industries and partner countries, as well as the intensive margin of average imports per province-gateway link. Our results thus support the idea that internal transportation infrastructure may play an important role in accessing international markets.

A particular channel for this regional response appears to be increased trade of transportation-intensive goods from regions that experienced the largest drop in transport costs. In particular, time-sensitivity of an industry matters for the effect of transport costs on the industry-level trade. This is in line with the recent empirical literature emphasizing time costs in international trade. While existing studies typically emphasize time in transit between countries or time lost in customs, our results highlight the importance of domestic transportation infrastructure in moving goods from the factory gate to the ports in a timely and predictable fashion. To the extent that efficient logistics in time-sensitive goods enable countries to take part in global supply chains and exploit their comparative advantages, our findings have important developmental implications.

Finally, note that this study focused on short-run effects by treating production locations as fixed. The aggregate trade response of an industry is a function of its initial location: if the supply of and demand for transport-intensive goods were initially agglomerated in provinces that had good market access to begin with, they would gain relatively little from transport cost reductions.[26] Many economic geography models suggest that the direction of this change

[26]The possibility of such selection should not cause any bias in our estimates as we are using long-term differences – which eliminate any time-invariant province-industry factors such as location. Thus, the long term effect of the infrastructure investment could be more drastic if transport intensive industries endogenously locate towards the now better-connected interior of the country.

depends on the relative strength of agglomeration forces versus trade costs, making it hard to predict. This makes studying the long term impact of this large-scale infrastructure project on regional outcomes such as population, wages and welfare an interesting avenue for future research.

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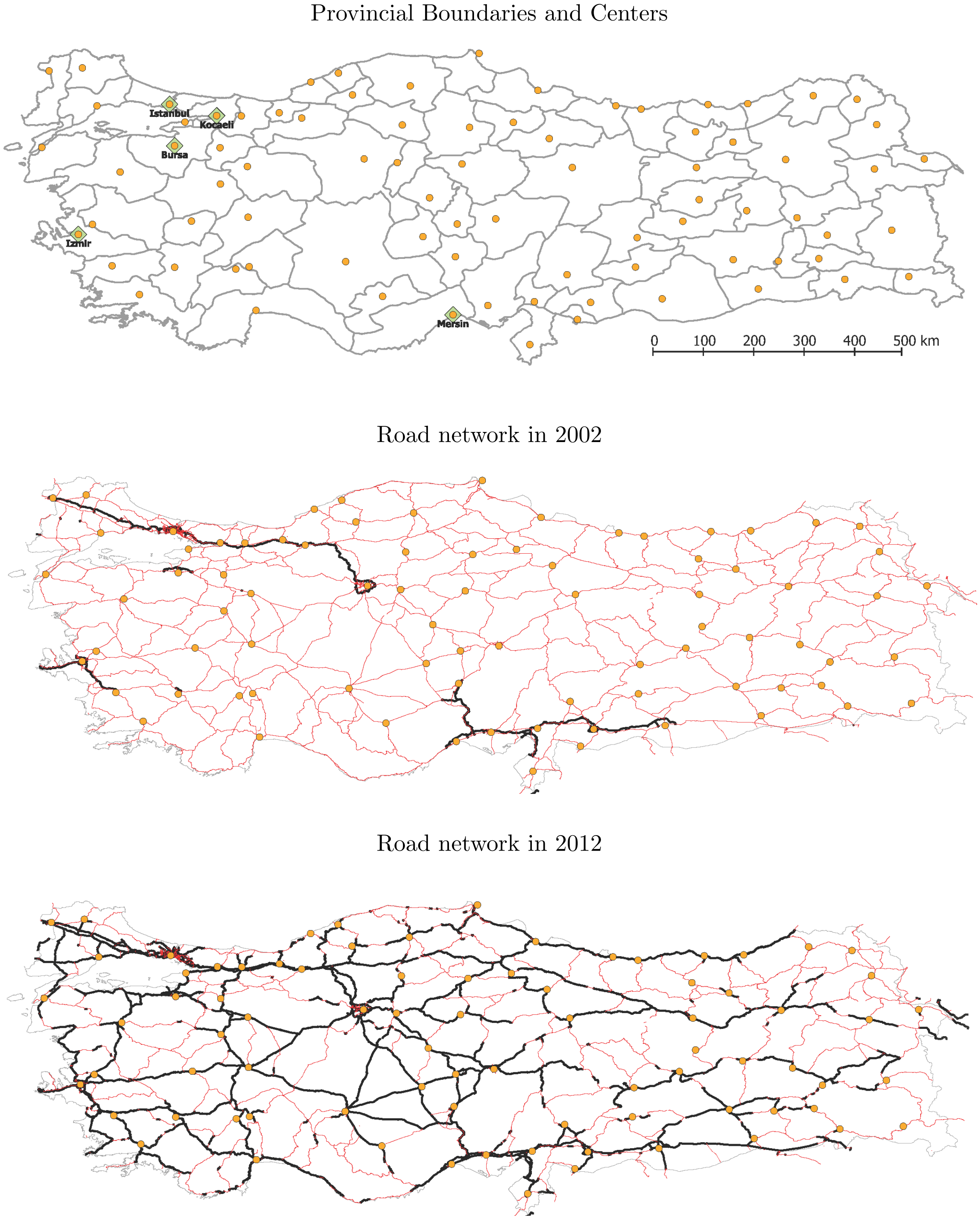
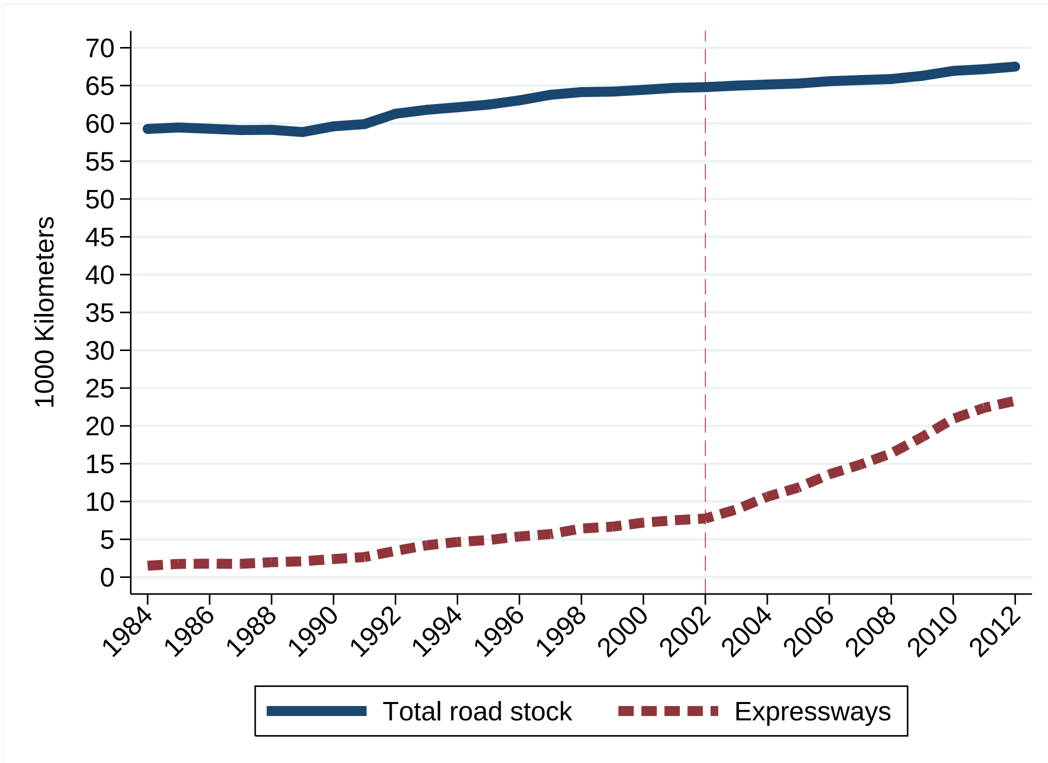
Figure 1: **Turkish Provinces and Roads**



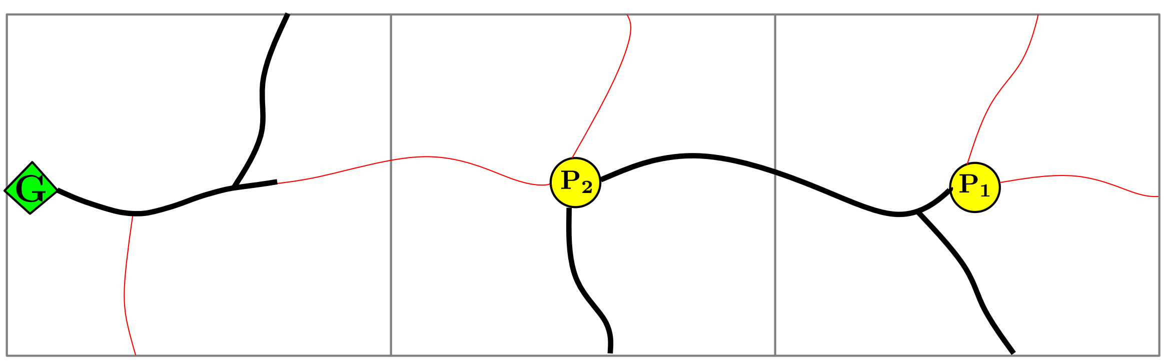
Notes: The top panel outlines provincial boundaries, provincial centers (orange nodes), and the top five gateway provinces (those labeled and marked with green diamonds). In the second and third panels, red lines are single carriageway roads and black lines are expressways. Geographical data used to plot the roads is downloaded from http://www.diva-gis.org.

Figure 2: **Roads over Time**



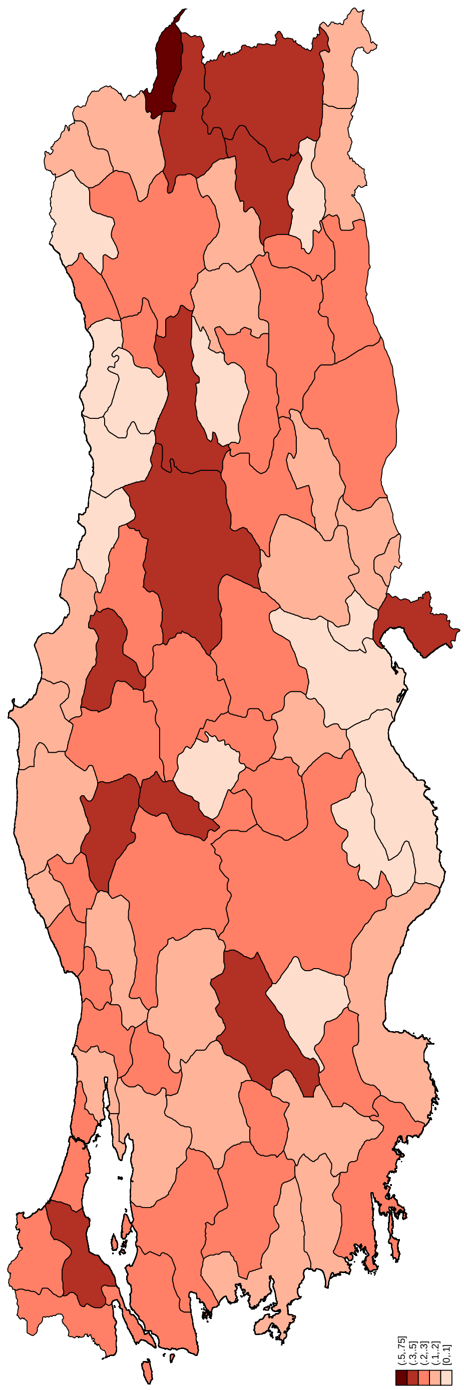
Notes: This figure plots total length of intercity roads and expressways between 1984-2002. The y-axis in thousand kilometers.

Figure 3: **Data Description: Provinces, Roads and Expressways**



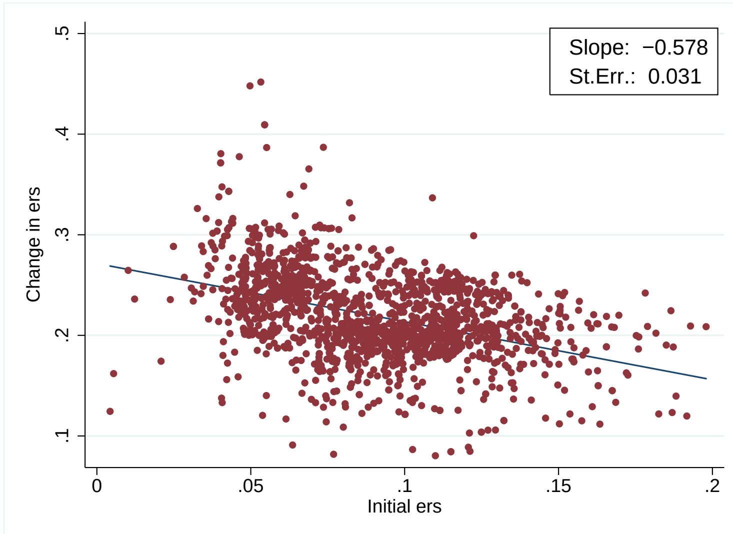
Notes: This illustration helps to describe the data. The tiles represent provincial boundaries, with (P_1, P_2, G) nodes representing provincial centers. G stands for gateway. Red (thin) lines are single carriage roads and black (thick) lines are dual carriage expressways. See text for details.

Figure 4: **Change in Expressway Road Shares Within Provincial Boundaries**



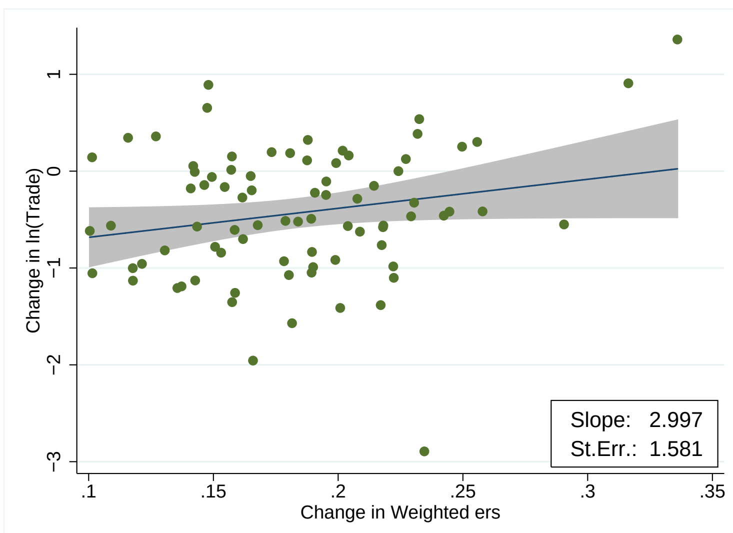
Notes: This map shows the absolute percentage point change in the expressway road share within each province: $(expressway_{p,2012})/(roadStock_{p,2003}) - (expressway_{p,2003})/(roadStock_{p,2003})$.

Figure 5: **Period Change in the Share of Expressways and its Initial Value**



Notes: The x-axis is the 2003 level of expressway share in roads connecting provinces and gateways (ers_{pg}^{2003}). The y-axis is the period change in this variable (Δers_{pg}).

Figure 6: **Road Capacity Improvements and Change in Trade Flows**



Notes: The x-axis is the change in each province's connectivity to gateways over the 2003-2012 period defined as $\sum_g \pi_{pg} \cdot \Delta ers_{pg}$, where π_{pg} is the share of gateway g in province p's total trade in 2003 and Δers_{pg} is the change in the share of expressways in total road stock on the route between p and g between 2003 and 2012 – capturing the road quality improvement for a province in accessing foreign markets. The y-axis captures the period change in trade at the province-level. Please see text for details.

Table 1: **Summary Statistics**

Trade statistics (in 1,000 USD)	*pg* sample		*pgc* sample		*pgi* sample	
	Mean	Std	Mean	Std	Mean	Std
Δ ln(exports)	1.692	2.111	1.478	2.182	1.790	2.484
Δ ln(imports)	1.486	2.169	1.168	2.423	1.361	2.359
Extensive margins of trade (Per province #)	2003		2012			
	Mean	Std	Mean	Std		
gateways, exports	7.519	4.051	12.188	4.537		
gateways, imports	7.163	3.354	9.247	3.727		
countries, exports	72.739	46.644	105.658	48.821		
countries, imports	55.088	36.570	73.169	42.685		
industries, exports	17.164	5.580	19.911	4.305		
industries, imports	17.295	5.695	19.647	4.489		
Distance (km, across *pg* pairs)	820	422				
	2003		2012			
	Mean	Std	Mean	Std		
Expressway share (%, across *pg* pairs)	9.1	3.1	31.1	4.1		

Table 2: **Gravity Estimation**

	(1)	(2)	(3)	(4)
	$\ln trade_{pg}^{f}$		$trade_{pg}^{f}$	
$\ln dist_{pg}$	-1.858***	-1.718***	-1.384***	-1.222***
	(0.084)	(0.072)	(0.086)	(0.077)
Regression	OLS	OLS	PPML	PPML
Observations	1376	1859	2686	3180
R^2	0.638	0.657	0.981	0.972
Fixed Effects	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f
Sample	2003-04	2011-12	2003-04	2011-12

Notes: All regressions are estimated with province-flow (p-f) and gateway-flow (g-f) fixed effects, where flows are exports or imports. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 3: **Baseline Results**

	(1) $\Delta \ln trade^f_{pg}$	(2) $\Delta \ln trade^f_{pg}$	(3) $\Delta \ln trade^f_{pg}$	(4) $\Delta \ln trade^f_{pg}$	(5) ΔRC_{pg}	(6) $\Delta \ln trade^f_{pg}$	(7) $\Delta \ln trade^f_{pg}$
Δers_{pg}	5.812**		0.610	21.06**			0.859
	(2.751)		(4.098)	(9.370)			(7.207)
ΔRC_{pg}		0.875***	0.822*			0.966**	0.858*
		(0.322)	(0.480)			(0.378)	(0.469)
$(ers^{2003}_{pg} - 1) \times \ln dist_{pg}$					-0.279***		
					(0.0456)		
$\ln dist_{pg}$					-0.0179		
					(0.0416)		
Regression	OLS	OLS	OLS	IV	OLS	IV	IV
Observations	1015	1015	1015	1015	1015	1015	1015
R^2	0.338	0.340	0.340	0.313	0.818	0.340	0.340
Fixed Effects	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f
AR Test Stat.				4.315		4.044	2.695
KP Test Stat.				55.92		548.9	40.59
DWH Test Stat.				2.795		0.113	0.129

Notes: Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent. We report Anderson-Rubin Wald test (AR test), first-stage Kleibergen-Paap F-statistic (KP test), and Durbin-Wu-Hausman F-statistic (DWH test).

Table 4: **Additional Controls**

	(1) $\Delta \ln trade^f_{pg}$	(2) $\Delta \ln trade^f_{pg}$	(3) $\Delta \ln trade^f_{pg}$	(4) $\Delta \ln trade^f_{pg}$	(5) $\Delta \ln trade^f_{pg}$
ΔRC_{pg}	1.975*	1.297**	1.250**	1.391**	2.180***
	(1.184)	(0.620)	(0.620)	(0.627)	(0.699)
Δers_{pg}	-6.388	-2.380	-3.874	-3.793	-3.620
	(6.854)	(7.262)	(7.531)	(7.355)	(7.345)
$ers^{2003}_{pg} \times \ln dist_{pg}$	-2.418				
	(2.302)				
ers^{2003}_{pg}	8.087				
	(14.54)				
$I\{dist_{pg} > median\}$		-0.182	-0.185	-0.158	-0.268
		(0.201)	(0.201)	(0.203)	(0.206)
$\Delta \ln PGDP^{04-11}_{pg}$			1.725	1.160	0.771
			(1.943)	(1.990)	(1.997)
$\Delta \ln trade^{96-01}_{pg}$				1.291	1.528
				(1.496)	(1.498)
$\Delta \ln trade^{96-01}_{pg} \times \ln dist_{pg}$				-0.257	-0.298
				(0.248)	(0.248)
$(MA_p \times SA_g)$					4.699**
					(1.955)
$(MA_p \times SA_g) \times \ln dist_{pg}$					-0.794**
					(0.327)
Regression	OLS	IV	IV	IV	IV
Observations	1015	1015	1015	1015	1015
R^2	0.343	0.341	0.341	0.343	0.346
Fixed Effects	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f
AR Test Stat.		2.599	2.328	1.935	3.096
KP Test Stat.		38.59	32.05	33.64	
DWH Test Stat.		0.211	0.358	0.224	0.411

Notes: MA_p, SA_g are market and supply access of provinces and gateways, respectively. They are estimated fixed effects from the gravity estimation in table 2. $I\{dist_{pg} > median\}$ is a dummy variable that takes on the value one if $dist_{pg}$ is above its median value in the data, and zero otherwise. $\Delta \ln PGDP$ is per capita GDP change in the pg route, available between 2004-2011 only. $\Delta \ln trade^{96-01}_{pg}$ is the total trade change in the pg route between 1996-2001. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent. We report Anderson-Rubin Wald test (AR test), first-stage Kleibergen-Paap F-statistic (KP test), and Durbin-Wu-Hausman F-statistic (DWH test).

Table 5: **Alternative Specifications**

	(1)	(2)	(3)	(4)
	$\Delta \ln trade^f_{pg}$	$\Delta \ln trade^f_{pg}$	$\Delta \ln trade^f_{pg}$	$\frac{2\cdot\left(trade^f_{pg,2012} - trade^f_{pg,2003}\right)}{trade^f_{pg,2012}+trade^f_{pg,2003}}$
ΔRC^{bw}_{pg}	0.911*			
	(0.466)			
Δers^{bw}_{pg}	-4.337			
	(2.772)			
$\Delta ers_{pg} \times dist_{pg}$		0.207**		
		(0.0902)		
Δers_{pg}		5.290	21.95**	-9.008***
		(5.561)	(9.290)	(2.427)
$\Delta time_{pg}$			-2.086*	
			(1.260)	
ΔRC_{pg}				0.867***
				(0.154)
Regression	IV	IV	IV	IV
Observations	1015	1015	1015	1687
R^2	0.338	0.342	0.311	0.259
Fixed Effects	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f
AR Test Stat.	1.757	3.303	4.911	10.82
KP Test Stat.	37.56	53.84	29.91	53.28
DWH Test Stat.	1.869	0.0481	1.606	2.771

Notes: Distance units in column 2 is in 100 km. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent. We report Anderson-Rubin Wald test (AR test), first-stage Kleibergen-Paap F-statistic (KP test).

Table 6: **Controlling for Selection**

	(1) Select	(2) $\Delta \ln trade^f_{pg}$	(3) $\Delta \ln trade^f_{pg}$	(4) $\Delta \ln trade^f_{pg}$	(5) $\Delta \ln trade^f_{pg}$	(6) $\Delta \ln trade^f_{pg}$
$(ers^{2003}_{pg} - 1) \times \ln dist_{pg}$	-0.468					
	(5.167)					
$\ln dist_{pg}$	-1.370					
	(4.704)					
$\ln trade^f_{pg,2003}$	0.151***					
	(0.0359)					
ers^{2003}_{pg}	2.357					
	(33.99)					
ΔRC_{pg}		0.858*	0.980**	0.988**	0.769	1.045**
		(0.469)	(0.470)	(0.458)	(0.474)	(0.483)
Δers_{pg}		0.859	-1.606	-1.489	-1.979	-3.361
		(7.207)	(7.300)	(7.044)	(6.982)	(6.508)
Regression	Probit	IV	IV	IV	IV	IV
Sample		All	$> 10th$ pctl	$> 25th$ pctl	$> 50th$ pctl	$> 60th$ pctl
Observations	765	1015	996	921	748	672
R^2		0.340	0.349	0.343	0.455	0.477
Fixed Effects	p,g	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f
AR Test Stat.		2.695	3.048	2.349	1.134	1.911
KP Test Stat.		40.59	39.51	42.08	41.29	39.31
DWH Test Stat.		0.129	0.217	0.0758	0.151	0.288

Notes: $Select_{pg}$ is an indicator variable that is equal to one if 2003 and 2012 trade flows are both positive, and zero otherwise. Sample in columns 3-5 are constructed based on the predicted probabilities from column (1). Robust standard errors in parentheses. We report Anderson-Rubin Wald test (AR test), first-stage Kleibergen-Paap F-statistic (KP test), and Durbin-Wu-Hausman F-statistic (DWH test). Hausman Test Stat. in the last column refers to the test statistic of a generalized Hausman test of the hypothesis that difference in coefficients between columns 3-6 is zero. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 7: **New Province-Gateway Trade Links**

	(1) New^f_{pg}	(2) New^f_{pg}	(3) New^f_{pg}	(4) New^f_{pg}	(5) New^f_{pg}	(6) New^f_{pg}
ΔRC_{pg}	0.0881*	0.107**		0.187**	0.186**	0.364***
	(0.0507)	(0.0498)		(0.0772)	(0.0786)	(0.0919)
Δers_{pg}		2.833***		2.261**	2.293**	-1.304
		(0.889)		(0.973)	(0.963)	(1.005)
ΔRC^{bw}_{pg}			0.103**			
			(0.0522)			
Δers^{bw}_{pg}			-0.868***			
			(0.322)			
$I\{dist_{pg} > median\}$				-0.0290	-0.0290	-0.0452*
				(0.0221)	(0.0221)	(0.0240)
$\Delta \ln PGDP^{04-11}_{pg}$					0.0118	-0.180
					(0.230)	(0.246)
$\Delta \ln trade^{96-01}_{pg}$						-0.0905
						(0.197)
$\Delta \ln trade^{96-01}_{pg} \times \ln dist_{pg}$						0.0124
						(0.0314)
$MA_p \times SA_g$						-0.250
						(0.220)
$(MA_p * SA_g) \times \ln dist_{pg}$						0.0233
						(0.0385)
Regression	IV	IV	IV	IV	IV	IV
Observations	3200	3200	3200	3200	3200	2669
R^2	0.152	0.115	0.149	0.117	0.117	0.133
Fixed Effects	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f
AR Test Stat.	1.401	12.23	2.526	13.47	13.79	7.330
KP Test Stat.	755.5	66.68	54.27	65.42	66.90	67.65
DWH Test Stat.	0.233	8.621	3.429	8.980	2.579	2.579

Notes: New_{pg} is equal to $Pr(trade^{f,Post}_{pg} > 0 \& trade^{f,Pre}_{pg} = 0)$. Robust standard errors in parentheses. For variable descriptions, see the notes to table 4. Significance: * 10 percent, ** 5 percent, *** 1 percent. We report Anderson-Rubin Wald test (AR test), first-stage Kleibergen-Paap F-statistic (KP test), and Durbin-Wu-Hausman F-statistic (DWH test).

Table 8: **Trade Partner and Industry Margins of Trade**

	(1)	(2) Countries	(3)	(4)	(5) Industries	(6)
	$\Delta \ln trade^f_{pg}$	$\Delta \ln(trade^f_{pg}/N^f_{pg})$	$\Delta \ln N^f_{pg}$	$\Delta \ln trade^f_{pg}$	$\Delta \ln(trade^f_{pg}/N^f_{pg})$	$\Delta \ln N^f_{pg}$
ΔRC_{pg}	0.858*	0.572	0.286*	0.858*	0.108	0.750***
	(0.469)	(0.411)	(0.167)	(0.469)	(0.418)	(0.153)
Δers_{pg}	0.859	2.281	-1.422	0.859	3.949	-3.090
	(7.207)	(6.445)	(2.627)	(7.207)	(6.358)	(2.395)
Regression	IV	IV	IV	IV	IV	IV
Observations	1015	1015	1015	1015	1015	1015
R^2	0.340	0.321	0.348	0.340	0.315	0.291
Fixed Effects	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f
AR Test Stat.	2.695	2.255	1.363	2.695	0.964	8.618
KP Test Stat.	40.59	40.59	40.59	40.59	40.59	40.59
DWH Test Stat.	0.129	0.190	0.122	0.129	0.0682	0.140

Notes: N^f_{pg} denotes the number of countries in columns 2 and 3, and the number of industries in columns 5 and 6. Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent. We report Anderson-Rubin Wald test (AR test) and first-stage Kleibergen-Paap F-statistic (KP test).

Table 9: **Exports versus Imports**

	(1)	(2)	(3)	(4)	(5)
	$\Delta \ln trade^f_{pg}$	$\Delta \ln trade^f_{pg}$	$\Delta \ln trade^f_{pg}$	New^f_{pg}	New^f_{pg}
ΔRC_{pg}	1.308**	0.973	1.643**	0.228***	-0.0146
	(0.571)	(0.712)	(0.770)	(0.0748)	(0.0655)
Δers_{pg}	-1.473	-5.113	2.168	2.400*	3.265***
	(8.936)	(11.61)	(11.30)	(1.334)	(1.183)
Regression	IV	IV	IV	IV	IV
Observations	754	377	377	1600	1600
R^2	0.242	0.426	0.369	0.110	0.0816
Flow	All	Export	Import	Export	Import
Margin	Intensive	Intensive	Intensive	Extensive	Extensive
Fixed Effects	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f	p-f,g-f
AR Test Stat.	3.426	1.249	3.070	8.461	4.732
KP Test Stat.	44.19	18.95	18.95	33.31	33.31
DWH Test Stat.	0.116	0.116	2.630	6.006	2.744

Notes: Robust standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent. We report Anderson-Rubin Wald test (AR test), first-stage Kleibergen-Paap F-statistic (KP test), and Durbin-Wu-Hausman F-statistic (DWH test).

Table 10: **Air Shares, Heaviness and Demand Elasticities of Industries**

ISIC	Industry	$Heavy_i$	Air_i	θ_i
15	Food products and beverages	1.340	0.082	4.563
16	Tobacco products	0.300	0.065	10.472
17	Textiles	0.375	0.165	4.357
18	Wearing apparel	0.101	0.232	4.081
19	Leather; manufacture of luggage, handbags, footwear	0.135	0.185	3.429
20	Wood and of products of wood and cork, except furniture	1.320	0.018	2.650
21	Paper and paper products	1.359	0.058	5.206
22	Publishing, printing and reproduction of recorded media	0.257	0.327	2.302
23	Coke, refined petroleum products and nuclear fuel	4.357	0.002	5.913
24	Chemicals and chemical products	0.647	0.540	3.050
25	Rubber and plastics products	0.457	0.119	3.245
26	Other non-metallic mineral products	3.599	0.103	2.532
27	Basic metals	0.783	0.073	3.016
28	Fabricated metal products, except machinery and equipment	0.344	0.466	2.562
29	Machinery and equipment n.e.c.	0.140	0.604	4.357
30	Office, accounting and computing machinery	0.143	0.637	4.080
31	Electrical machinery and apparatus n.e.c.	0.141	0.675	2.599
32	Radio, television and communication equipment and apparatus	0.141	0.675	2.599
33	Medical, precision and optical instruments, watches and clocks	0.063	0.777	2.863
34	Motor vehicles, trailers and semi-trailers	0.205	0.117	3.868
35	Other transport equipment	0.039	0.901	7.542
36	Furniture; manufacturing n.e.c.	0.291	0.656	2.631

Notes: Air_i and $Heavy_i$ stand for air share and heaviness of industry-level imports into the UK in 2005. Precisely, air share is imports by air divided by total imports by air and vessel. Heaviness is the natural logarithm of the weight/value ratio of imports by vessel. θ_i denotes the demand elasticity of industry i, estimated by Soderbery (2015) using Broda and Weinstein (2006) methodology.

Table 11: **Transport Intensity**

	(1) $\Delta \ln trade^f_{pgi}$	(2) $\Delta \ln trade^f_{pgi}$	(3) New^f_{pgi}	(4) New^f_{pgi}
$\Delta RC_{pg} \times Air_i$	0.907*	0.884*	0.104**	0.0833*
	(0.481)	(0.473)	(0.0491)	(0.0491)
$\Delta RC_{pg} \times Heavy_i$	1.129**	1.113**	0.0879	0.0752
	(0.541)	(0.555)	(0.0581)	(0.0583)
$\Delta ers_{pg} \times Air_i$	-3.474	-3.579	-0.556	-0.480
	(2.998)	(2.949)	(0.473)	(0.474)
$\Delta ers_{pg} \times Heavy_i$	-4.684	-4.740	-0.592	-0.559
	(3.265)	(3.351)	(0.515)	(0.519)
$\Delta RC_{pg} \times \theta_i$		-0.00275		-0.0359**
		(0.215)		(0.0170)
$\Delta ers_{pg} \times \theta_i$		-0.376		0.116
		(1.292)		(0.173)
Regression	IV	IV	IV	IV
Observations	5299	5299	12203	12203
R^2	0.008	0.009	0.056	0.056
Fixed Effects	p-g-f	p-g-f	p-g-f,i	p-g-f,i
AR Test Stat.	5.764	4.284	2.429	2.404
KP Test Stat.	150.5	83.64	17.18	11.68
DWH Test Stat.	0.868	1.053	0.933	0.773

Notes: Standard errors in parentheses are clustered at the *pg* level. Significance: * 10 percent, ** 5 percent, *** 1 percent. New^f_{pgi} is equal to 1 if $trade^{f,2012}_{pgi} > 0$ and $trade^{f,2003}_{pgi} = 0$, and zero otherwise. See text for further details.