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 the quality of internal transportation infrastructure affects regional access to international markets. Three results emerge. First, we estimate that the difference in the distance elasticity of trade flows between low-quality and high-quality roads lies between 0.1 and 0.27. Second, our estimates imply that this road infrastructure project generates a 10-year discounted stream of additional export revenues that amount to between 9 and 19 percent of the value of the investment. Third, while the exports of all industries within a given region increase in response to improvements in connectivity to the international gateways of the country, the magnitude of this increase is larger the more transportation-intensive an industry is. Accordingly, we also observe an increase in the regional employment and revenue shares of such industries. Our results support the hypothesis that internal trade costs can be a determinant of international specialization and comparative advantage.

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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. Analyses of transportation costs in international trade rarely consider the domestic segment of shipments in isolation. Bilateral distances in gravity-based quantitative models, which, among other things, proxy for transport costs, 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. 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 port to port sea leg. Atkin and Donaldson (2012) estimate that intranational trade costs in Ethiopia and Nigeria are 7 to 15 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 the trade-related benefits of transportation infrastructure investments.

In this paper, we analyze the outcomes from a large-scale public investment in Turkey aimed at improving the quality of the road network. Between 2003 and 2012, the country increased the share of four-lane expressways in its national road stock from 11 to 35 percent. The expansion of existing two-lane roads into divided four-lane expressways significantly improved the quality of roads while the quantity of roads (i.e., the total length of the road network) 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. Exploiting this variation, we estimate that the investment under study generates a 10-year stream of export revenues that amounts to between 9 and 19 percent of the cost of the investment. Our results are robust to alternative specifications and using the instrumental variables method. Next, we show that transportation-intensive industries displayed higher export growth in regions with above-average improvements in connectivity. This constitutes a plausible channel for the aggregate response of regional exports and strengthens our identification. Finally, transportation-intensive industries display higher revenue and employment growth relative to other industries in the very same regions, which is consistent with trade outcomes. This finding confirms that domestic transportation infrastructure can affect regional specialization.

Recent work highlights the prevalence and importance of the issues that we explore. As noted above, Atkin and Donaldson (2012) estimate large internal trade costs in Ethiopia and Nigeria. Cosar and Fajgelbaum (2013) 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 (2013) incorporate realistic topographical features of geography into a spatial model of trade and estimate the rates of return to the US Interstate Highway System. We complement these studies by providing evidence on how a major improvement in transportation quality 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] We differ from these studies in our focus on a single country, in our ability to measure road quality and its effect on transport costs more precisely, and in our exploration of the channels through which transportation infrastructure exerts its effects. Using a multiregion general equilibrium model of trade, Donaldson (2012) and Donaldson and Hornbeck (2013) analyze the welfare gains from railroads in India and the United States, respectively. We add to this literature by analyzing the impact that a recent infrastructure project of similar scale had on the international trade of a developing country and by showing that increased trade in time-sensitive and heavy industries constitute a major channel through which aggregate gains may accrue. To the extent that reducing internal transport costs helps developing countries participate in global supply chains, our results have important implications for industrial and commercial policies.

Other studies of particular developing country experiences typically measure the effect of road quantity rather than quality. 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.

While direct evidence is scarce, several quantitative studies estimate the trade-cost-reducing effects of better road quality. Allen and Arkolakis (2013) find that the cost of a coast-to-coast shipment in the United States via the interstate highway system is around a third the cost of the same trip via the old motorway system. Using cross-sectional data from Colombia measuring pavement quality of roads by engineering methods (the International Roughness Index), Blyde (2012) estimates that the cost of delivering exports from remote locations to the ports decreases by 20-30 percent when the quality of road pavement on the route increases from poor to good. The nature of the road quality investment in our setting relies less on external measurement

[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.

and allows for an alternative identification.

Conceptual Framework

In a wide range of models, trade costs affect trade volumes and specialization patterns. Estimates of gravity-type equations using data on international or intranational trade flows find a persistent role for distance. Among the various distance-related costs of delivering goods to consumers, transportation constitutes an important component. In turn, transportation costs are a function not only of the distance between producers and consumers but also of the availability and quality of infrastructure, such as roads and 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.[2] In our empirical investigation, we treat the aforementioned infrastructure investments in Turkey as an observable shock to the cost of domestic transportation. Since we do not observe internal trade flows, the analysis is restricted to the effect that these investments had on the international trade of regions within the country. Given their locations, regions benefited from reductions in transportation costs involved in accessing foreign markets to different degrees. Our first results exploit this spatial variation: regions whose connectivity to the international trade gateways improved more than others experienced a higher-than-average increase in trade.

The identification of regional market access is based on the premise that the widening of two-lane roads to divided four-lane expressways improved the quality of road infrastructure, and therefore alleviated the negative impact of remoteness. There are several mechanisms for such an effect. Reduced congestion 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

[2] Anderson and van Wincoop (2004) estimate an ad valorem tax equivalent of trade costs between industrialized countries around 170 percent. Of this, 21 percent is international transportation costs, and 55 percent is domestic distribution costs.

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.

In order to uncover the channels through which province-level trade respond, we rely on the idea that goods differ in their transportation intensity. This may be due to two industry characteristics: sensitivity to the length and precision of delivery times, and the heaviness of an industry's output. For some agricultural goods, time-sensitivity may arise simply due to perishability. The literature recognizes other causes of time sensitivity 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 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 context, one would expect a higher increase in exports of time-sensitive goods from provinces experiencing a higher than average improvement in connectivity. Measuring industries' time sensitivity by the air share of their imports to the United Kingdom or to the United States, we find support for this prediction. This is in line with Evans and Harrigan (2005), who provide evidence on the importance of timeliness in determining international trade patterns.

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. Consistent with and complementary to this result, we find that provinces with improved international market access experienced a relatively higher export increase in industries with high weight to value ratio.

The next section introduces the data and describes the empirical implementation. The results are presented in section 3.

2 Data and Empirical Implementation

2.1 Background

Turkey is an upper-middle-income country with a large population (76 million as of 2012) and a diversified economy. The country is the world's 17*th*-largest economy and 22*nd*-largest exporter by value. 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 exports. Turkey is the fifth-largest exporter to the European Union and its seventh-largest importer.

Administratively, Turkey is divided into 81 contiguous provinces (*il* in Turkish) of varying geographic and economic size.[3] 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. While municipalities are responsible for the construction and maintenance of urban roads, the central government plans, constructs, and maintains interprovincial roads outside of urban centers. Figure 2 outlines provincial boundaries and centers.

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.[4] Despite the importance of trucks and light commercial vehicles in freight transportation, the quality of interprovincial roads was considered quite inadequate 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 aimed at improving the quality of the country's road infrastructure. The project primarily envisaged the transformation of two-lane roads into divided four-lane expressways. As a result, the length of divided four-lane expressways increased by more than threefold during the 2003-2012 period, while total road stock remained essentially unchanged (figure 1). This observation constitutes one of the distinguishing features of our paper with respect to the related literature; while existing studies focus mostly on how construction of new roads affects exports, we focus

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

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

on how improvements in the quality of existing roads affect regional trade.

The way in which this large-scale investment in the road infrastructure was undertaken in Turkey alleviates endogeneity concerns related to the selection of provinces where higher trade growth was anticipated, and makes it possible to identify the effect on regional exports. The investment aimed at expanding the capacity of existing roads rather adding new segments. While particular road segments were not randomly assigned for upgrades, they were not individually selected either: the long-term goal is to improve connections between provincial centers across the country to form a comprehensive grid network (figure 2). The investment was centrally planned and financed from the central government's budget. Therefore, local administrations were not directly involved in the decision-making process or in financing.[5] Banerjee, Duflo, and Qian (2012) document that railroad construction in China followed a similar investment strategy of connecting historical cities. While their research question is different—they use this exogenous variation to identify the effect of transportation infrastructure on the differential growth rates of regions between historical urban centers—there is a similarity in the sources of exogeneity: both infrastructure projects aim to form a wide network rather than benefit certain parts of the country. In short, the investment was not designed to boost exports from regions that are lagging in terms of exporting, or to support regions that are already successful exporters. Finally, the fact that Turkey is a small open economy reduces the likelihood that two Turkish regions compete directly with each other in a foreign market. In other words, improvements in transport infrastructure are likely to create more trade rather than divert it across cities.

External evidence confirms our conviction that the investments described above 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). LPI values range between 0 and 5; a higher LPI value indicates a more developed transportation sector as perceived by industry experts. In 2007,

[5] 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).

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, international shipments, logistics competence, tracking and tracing, and timeliness. In 2007, Turkey ranked 39*th* among 150 countries for the quality of trade- and transport-related infrastructure, and 52*th* 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.This evidence supports the claim that the large-scale public investment in road infrastructure undertaken in Turkey during the 2000s has improved the quality of its transport infrastructure.

One may argue that Turkey's improvement in the LPI rankings resulted not from improvements in the quality of road infrastructure, but from improvements in other transport infrastructure. The Global Competitiveness Report, published by the World Economic Forum, provides direct evidence of an overall improvement in the quality of road infrastructure in Turkey over the 2006-2012 period. The Global Competitiveness Report publishes country rankings based on the quality of their road infrastructure. 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 and moved up 10 places to 43*th* among 148 countries.[6]

For such improvements to have some effect on regional exports, they should reduce the time it takes to transport goods within the country. One of the components of the domestic LPI is "export lead time," which measures the time it takes to transport goods from the point of origin to ports/airports. The LPI data show that the median export lead time in Turkey decreased from 2.5 days in 2007 to 2 days in 2012. Considering time as a trade cost, such evidence further motivates us to test the hypothesis that quality-enhancing investment in road infrastructure in

[6]Demir (2011) also uses the 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.

Turkey increased regional exports during the 2003-2012 period.

2.2 Data

We employ data from two sources. Data on the stock of total and divided roads at the province level for the 2003-2012 period are provided by the Republic of Turkey General Directorate of Highways. To be precise, our data inform us about the length of total roads and divided roads within provincial boundaries at each year in our panel. We do not have detailed geographical information about particular segments. Data on province-level manufacturing exports, imports, and the number of exporters for the 2003-2012 period are provided by the Turkish Statistical Institute (TUIK). Province-level exports are disaggregated by country of destination and 24 tradable industries (in 2 digit ISIC Rev.3 classification). Similarly, imports are reported by industry and source country. We complement our dataset with data on province-level population, also provided by TUIK, and the GDP of each trade partner as published in the 2013 World Development Indicators.

2.3 Measurement and Empirical Implementation

Constructing a measure of transport costs that captures the variation in the connectivity of provinces to foreign markets is crucial for our exercise. To do this, we adapt a common specification from the literature to our setting so as to capture the differential cost of shipping on roads of varying quality. We then specify a general gravity equation to estimate the effect of the infrastructure investment on the distance elasticity of trade flows.

In what follows, we consider each province's connectivity to the main gateway provinces, which together account for more than 90 percent of total exports.[7] For each province-gateway pair pg, we find the shortest path and construct a set of provinces that one has to pass through on the way from province p to the gateway province g, which is denoted by J_{pg}. Figure 3,

[7] These gateway provinces are Bursa, Istanbul, Izmir, Kocaeli, Mersin, Samsun, and Kilis. The first six are home to major maritime ports, whereas the last one contains the border crossing to Syria. The port of Istanbul accounts for around half of total exports. See figure 2.

mimicking the real map in figure 2, illustrates an example. Provincial centers are represented in nodes within their administrative province borders. The shortest path from province P_1 to gateway province G passes through province P_2. To address potential endogeneity concerns, we exclude the province itself from the set. Thus the set J_{P_1G} consists of P_2 and G.

Next we calculate the share of divided roads in the total road stock on route pg:

$$drs_{pgt} = \frac{\sum_{j \in J_{pg}; j \neq p} divided\_road_{jt}}{\sum_{j \in J_{pg}; j \neq p} total\_road_{j,2003}}$$

where $divided\_road_{jt}$ is the length (in km) of the divided road stock in province j in year t, and $total\_road_{j,2003}$ is the length of total road stock at the end of 2003.[8] The ratio above measures the quality of the road stock on the route pg for each year and thus captures the time variation in improved connectivity between provinces and international gateways. Since road infrastructure is shared, multiple provinces benefit from an improvement in the quality of road infrastructure along a trade route. This minimizes endogeneity concerns regarding our measure: province-specific considerations are less likely to play any role in the decision to invest along a major trade route. Going back to the example in figure 3, on the route between province P_1 and gateway province G, the total stock of roads is illustrated as lines within provincial boundaries, and the stock of divided roads is represented by thick black lines. In this illustration, drs_{p_1g} is the fraction of total road length within the borders of (P_2, G) that is divided (thick black).

The cost of transportation between province p and gateway g is an increasing function of distance. In particular, the elasticity of transport costs with respect to distance is a weighted average of distance elasticities associated with high-quality divided roads and low-quality basic roads, and the weight is determined by the share of divided roads on the route pg:

$$TC_{pgt} = dist_{pg}^{\tau_n drs_{pgt} + \tau_o(1-drs_{pgt})}, \tag{1}$$

[8]We fix the denominator because of additions to the two-lane road stock over the years. When we use the yearly total road stock $total\_road_{jt}$ instead, there are a few observations (pgt) with a year-to-year decline in the divided road share due to more two-lane roads being built than the upgrading of the old. These additions are quantitatively small, and more importantly, all upgrades were done on the initial stock of roads. To be conceptually consistent with this, we fix the initial stock. The results are robust to using yearly values.

where τ_n, τ_o are the distance elasticities associated with new, high-quality divided roads and old, low-quality basic roads, respectively. We can rearrange (1) to obtain

$$TC_{pgt} = dist_{pg}^{\tau(1-drs_{pgt})} dist_{pg}^{\tau_n}, \tag{2}$$

where $\tau = \tau_o - \tau_n$. One of our objectives is to estimate τ. Given the discussion above, we expect the cost of shipping on high-quality new roads to be less distance elastic, i.e. $\tau > 0$.

Time-variation in our transport cost measure is driven by the change in the share of divided road stock on the route pg over time, and this is captured by the first term in (2). The second, time-invariant term will be captured by province fixed effects in the estimation. To give a better sense of the identifying variation, figure 4 plots the level of road quality improvement for each province from 2003 to 2012 against its remoteness. On the x-axis, provinces are ordered in terms of their remoteness, defined as a weighted average of their distance from the seven major gateway provinces:

$$\sum_g \pi_{g,2002} \cdot dist_{pg},$$

where $\pi_{g,2002}$ denotes the share of exports shipped through the gateway g in 2002.[9] On the y-axis, the ratio of $drs_{p,2012}$ to $drs_{p,2003}$ shows the period-change in the share of divided road stock within provincial boundaries. The ratio is uniformly greater than one, implying that all provinces benefited from improved road quality, albeit to varying degrees, during the 2003-2012 period. The most remote provinces experienced the largest gains both within their boundaries and thus on their routes to the gateway provinces.

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

$$X_{pgt} = \omega_p \omega_{gt} TC_{pgt}^{-\theta}, \tag{3}$$

where ω_p captures time-invariant province-level variables that affect its international trade, and ω_{gt} captures time-varying factors that affect international demand and supply through gate g

[9] Export shares of gateways do not change dramatically during the period under consideration.

(such as income in destination countries that can be reached through g). $\theta > 0$ denotes the elasticity of trade flows with respect to transportation costs. Substituting TC_{pgt} from (2) and taking logs, we obtain

$$\ln X_{pgt} = \ln \omega_p + \ln \omega_{gt} - \theta \ln \left[dist_{pg}^{\tau(1-drs_{pgt})} \right] - \theta \ln \left[dist_{pg}^{\tau_{hq}} \right]. \tag{4}$$

With data on X_{pgt} at hand, one could estimate this relationship and back out τ, τ_{hq} for a given level of θ. Unfortunately, we only observe total province-level trade X_{pt} rather than provinces' trade flows through each gateway. To facilitate estimation, we substitute g specific terms on the right hand side with average values using gateways' export shares $\pi_{g,2002}$ fixed at the initial date and write

$$\ln X_{pt} = \ln \omega_p + \delta_t - \theta \ln \left[\sum_g \pi_g dist_{pg}^{\tau(1-drs_{pgt})} \right] + \theta \ln MA_p, \tag{5}$$

where

$$\delta_t = \ln \left(\sum_g \pi_g \omega_{gt} \right),$$

$$\ln MA_p = -\ln \left(\sum_g \pi_g dist_{pg}^{\tau_n} \right).$$

The last term $\ln MA_p$ captures the time-invariant market access of province p, which decreases with its average distance to gateways.[10] This term, together with $\ln \omega_p$, can be absorbed into a province fixed effect δ_p. The term δ_t is a time-varying shifter common to all provinces, and it can be absorbed into a time fixed effect in the estimation. The term in square brackets in (5) captures the time-varying market access of province p due to improvements in the quality of road infrastructure.

[10]Due to lack of detailed geographical data on roads and the speed associated with old and new roads, we assume away optimal re-routing from the 2003 paths. Our bilateral distances are shortest distance paths on the 2003 network.

We can collect terms in (5) to obtain the following specification:

$$lnX_{pt} = \delta_p + \delta_t - \theta \cdot \ln \left[\sum_g \pi_g dist_{pg}^{\tau(1-drs_{pgt})} \right] + \epsilon_{pt}, \tag{6}$$

which can be estimated using a non-linear least squares (NLS) routine to obtain an estimate of τ for common values of θ used in the literature.

Alternatively, one can estimate the following linear approximation using ordinary least squares (OLS):

$$\ln X_{pt} = \delta_p + \delta_t + \beta \cdot \underbrace{\ln \left(\sum_g \pi_g dist_{pg}^{(1-drs_{pgt})} \right)}_{\ln(TC_{pt})} + \epsilon_{pt}, \tag{7}$$

where

$$\ln \left[\sum_g \pi_g dist_{pg}^{\tau(1-drs_{pgt})} \right] \approx \tau \ln \left(\sum_g \pi_g dist_{pg}^{(1-drs_{pgt})} \right).$$

Again, τ is not separately identified in (7). With an estimate of $\beta = -\theta\tau$ and a given value for θ, we can back out τ. We are now ready to present the results for both the NLS specification and the OLS approximation.[11]

3 Empirical Results

3.1 Transport Costs and Regional Trade

We begin our analysis at the province level by estimating (6) in long-run differences between 2003-2012 using NLS. Estimation in long differences eliminates time-invariant province characteristics and the potential serial correlation problem, and helps us gauge the long-run effect.

[11] For a wide range of τ values, this approximation works quite well in our data for all cities except for Istanbul: the deviation from the exact term is a function of average remoteness and Istanbul is the least-remote city with the shortest average distance $\sum_g \pi_g dist_{pg}$ due to its large export share. The results are robust to excluding Istanbul from estimation.

We estimate the following specification:

$$\Delta \ln(X_p) \;=\; \delta + \theta \cdot \Delta \ln \left[\sum_g \pi_g dist_{pg}^{\tau(1-drs_{pg})} \right] + \epsilon_p, \tag{8}$$

where $X = \{trade, exp, imp\}$, and $trade$ denotes the value (in USD) of the sum of exports (exp) and imports (imp). Δ operator denotes the difference of the variable between the initial and terminal years in our data, i.e. $\Delta y = y_{2012} - y_{2003}$.

We assume $\theta = 4$, which falls within the range of common values used in the literature (Simonovska and Waugh, 2013). Table 1 presents the results. We estimate a positive and significant difference for the distance elasticities between low and high-quality roads for total trade and exports, but not for imports. The estimated difference in the distance elasticity between low-quality old roads and high-quality divided roads is 0.25 for total trade, and slightly higher for exports.

Next we estimate (7) using OLS both in levels and in long-differences. Estimation in levels is based on the following specification:

$$\ln(X_{pt}) \;=\; \delta_p + \delta_t + \beta \cdot \ln(TC_{pt}) + \epsilon_{pt}. \tag{9}$$

In the estimating equation (9), we include province fixed effects δ_p to control for time-invariant province characteristics, such as time-invariant market access and productivity. We also include year fixed effects to account for time-varying shocks common to all provinces. Given that $\beta = -\theta\tau$, we expect $\beta < 0$.

To estimate the long-run effect over the period 2003-2012, we estimate the following specification using OLS:

$$\Delta \ln(X_p) \;=\; \beta_0^d + \beta_1^d \cdot \Delta \ln(TC_p) + \beta_2^d \cdot \pi_{p,2002} + \beta_3^d \cdot \Delta_{96-02} \ln(X_p) + \epsilon_p. \tag{10}$$

In this specification, we exploit the flexibility of OLS and include additional province-level controls on the right-hand-side. First, we include $\pi_{p,2002}$ to control for the size of province-level

X_p, where $X_p = \{trade_p, exp_p, imp_p\}$, relative to its country-level size at time $t = 0$. Second, we include $\Delta_{96-02} \ln(X_p)$ to capture the pre-investment trend of province-level X_p between 1996-2002. These two variables should control for any potential bias that may arise from selection of provinces based on their initial size of trade or their potential as an important future supplier of exports. Table 2 reports the results.

Column 1 in table 2 presents the results obtained from estimating (9) using the sum of province-level exports and imports as the dependent variable. Our parameter of interest β has the expected sign and is highly significant at the 1 percent level. The coefficient estimate is also economically significant: a 1 percent decrease in our transport cost measure increases province-level trade by about 0.8 percent. As presented in the second and third columns of the same table, the coefficient estimates are similar in magnitude for exports and imports, separately. In columns 4-6, we estimate (10) for total trade, exports, and imports. This specification is highly demanding as we also control for the initial size of the dependent variable and its pre-investment trend at the province level. The coefficient estimates of β for total trade and exports are very close to the corresponding estimates in columns 1 and 2. They retain their significance at the 10% level. Nevertheless, the coefficient estimate for imports loses its significance. For $\theta = 4$, the estimate of β for trade presented in column 4 implies $\tau = 0.21$, which is consistent with our NLS estimate presented in table 1. For $\theta \in [3, 8]$, the difference in distance elasticity between low and high-quality roads lies between 0.1 and 0.27. Our results thus provide evidence that there exists a significant cost difference between shipping on low-quality and high-quality roads.

While our estimates for total trade flows and exports are very close, we do not obtain robust results for imports. One potential reason could be the high-level of intermediation observed for imports relative to exports. Firms can engage in international trade either directly or through trade intermediaries and wholesalers. If a firm located in a certain province exports (imports) directly, the true source (destination) province of this transaction will be accounted for in our data. If, on the other hand, a trade intermediary is involved, the transaction will be added to the trade of the province in which the intermediary is located. Since trade intermediaries and wholesalers are more likely to be located in the country's big port cities, this will lead to mismeasurement in geographical destination (source province) of imports (exports). While our dataset does not contain information about the export mode, there is reason to suspect that trade intermediation, and thus mismeasurement, is more prevalent in importing (Bernard, Jensen, Redding, and Schott, 2010). Using a survey of Turkish exporters, Abel-Koch (2013) documents that only 17 percent of exports are intermediated. On the other hand, anecdotal evidence suggests that wholesalers based in Istanbul act as distributors of many imported products to the entire country. Therefore, we focus on exports for the rest of the analysis, keeping in mind that we obtain similar results for total trade flows. Also, given the similarity of estimates, we use OLS as the estimation method in the rest of the paper.

Next, we break down province-level exports into extensive and intensive margins. We consider two extensive margins: one in terms of the number of export destinations, and the other in terms of the number of exporters located in a province. The intensive margin then refers to the average value of exports per firm-destination at the province level. If goods exported to a destination can only be shipped through a particular port, an improvement in the quality of road infrastructure may then facilitate a province's access to destinations that would otherwise be prohibitively expensive to export to. This extensive margin of markets is estimated by

$$\ln(ndest_{pt}) = \delta_p + \delta_t + \beta^{ext} \cdot \ln(TC_{pt}) + \epsilon_{pt}, \tag{11}$$

where $ndest_{pt}$ denotes the number of export destinations served by province p in year t. To estimate the extensive margin of exporters, we take the natural logarithm of $nfirm_{pt}$, the number of exporters. Finally, a fall in shipping costs may also increase exports to current destinations in the intensive margin:

$$\ln\left(\frac{exp_{pt}}{ndest_{pt} \cdot nfirm_{pt}}\right) = \delta_p +_t + \beta^{int} \cdot \ln(TC_{pt}) + \epsilon_{pt}. \tag{12}$$

In this specification, the dependent variable is average exports per firm-destination by a province. Table 3 reports the results. When estimating (11) and (12), we control for province and time fixed effects. The results are in line with our expectations. The extensive margin in terms of the number of destinations is the main channel through which a fall in transport costs increases province-level exports. There is no evidence that a fall in transport costs helped firms start exporting, or existing exporters increase the volume of their exports to a given destination over the period 2003-2012. Results we obtain from estimating (11) and (12) in long differences do not change our conclusion.

Next, we exploit the richness of our dataset and control for time-varying destination and industry characteristics. First we estimate the following specification with destination-year fixed effects, which control for, among other things, importers' demand:

$$\ln(exp_{pdt}) = \delta_p + \delta_{dt} + \beta \cdot \ln(TC_{pt}) + \epsilon_{pdt}, \tag{13}$$

where exp_{pdt} denotes the value (in USD) of exports of province p to country d in year t, and δ_{dt} are destination-year fixed effects. This specification also controls for the possible regional effects of a number of free trade agreements signed during the 2003-2012 period. For instance, a free trade agreement between Turkey and Georgia came into force in November 2008, and Turkey's exports to Georgia more than tripled in 5 years. If Turkish provinces close to Georgia, which are remote to the main ports of the country, have experienced a considerable reduction in their transport costs and an increase in their exports, then our previous estimates might be capturing a spurious relationship. If that is the case, we would expect to find a coefficient of smaller magnitude when we control for destination-year effects.

Similarly, industry composition of province-level exports may also affect our results. Export demand for some industries could have increased during the period under consideration. If the export share of such industries is large in provinces that have experienced a high reduction in the cost of accessing international gateways, then our parameter of interest would be biased. To control for this possibility, we include industry-year fixed effects δ_{it} and estimate the following specification:

$$\ln(exp_{pit}) = \delta_p + \delta_{it} + \beta \cdot \ln(TC_{pt}) + \epsilon_{pit} \tag{14}$$

where exp_{pit} denotes the value (in USD) of exports of province p in industry i and year t. Table 4 reports the results. Across all specifications, regardless of whether we estimate in levels or in long differences, our parameter of interest is estimated to be both statistically and economically significant. When we control for time-varying destination characteristics in column 3, the coefficient estimates shrink (in absolute value), but it is still highly significant. The coefficient from the long-run difference specification in column 4 is comparable to its value in column 5 of table 2.

On overall, our results imply a sizeable effect of road quality investments on regional trade. To interpret distance coefficients as ad-valorem equivalents, we calculate the cost of shipping on old and new roads to a destination at mean distance (752 km) and the additional cost of one standard deviation increase in distance (371 km). Since our estimation only identifies $\tau = \tau_o - \tau_n$, we assume $\tau_o = 1$. In this case,

$$\frac{TC(752\text{ km} + 371\text{ km})}{TC(752\text{ km})} - 1 = 0.495,$$

i.e. the cost of shipping to an additional standard deviation of distance implies a 50% increase in transport costs at mean distance.[12] For $\tau = 0.25$ from column 1 of table 1, the distance elasticity of new roads is $\tau_n = 0.75$. This implies a 35% increase in the cost of shipping an additional standard deviation beyond mean distance.

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 export revenues between 9 and 19 cents.[13] It is worth noting that welfare gains should be much larger, as we do not take into account, among other things, trade between provinces. For instance, Allen and

[12] We simply calculate $TC(dist) = dist^{\tau_i}$ for $\tau_i = \tau_o, \tau_n$.

[13] The calculation is based on the estimate presented in column 5 of table 2. We consider a hypothetical route with the mean distance (752 km), and mean divided road share (0.11) in 2003. To reduce transport costs by 1 percent on this route, $7.52^{(1/(1-0.11))} = 9.65$ km of roads have to be transformed into divided roads. The General Directorate of Highways publishes annual activity reports that provide information on the cost of building 1 km of a four-lane road. Using the average cost over the 2003-2012 period, we calculate the cost of building 9.65 km of a four-lane road. Next, we use our most conservative estimate, -0.721 from column 5 of table 2, to calculate the value of exports (at the mean) generated by a 1 percent decrease in transport costs. The numbers provided in the text are the present value of a 10-year stream of exports generated by a one-dollar investment in road infrastructure for discount factors between 0.1 and 0.05.

Arkolakis (2013) estimate a rate of return on investment on the US Interstate Highway System of at least 100 percent.

Instrumental Variables Approach

To control for the possible endogeneity of the public investment program implemented in Turkey during the period 2003-2012, we have taken a number of steps. First, we exclude the source province when constructing the quality measure on the route between the province and major gateway provinces. Second, we estimate our baseline specification not only in levels but also in long differences to eliminate any unobserved province-level factors. Third, when we use long differences in the estimation, we control for provinces' pre-existing trends and initial shares in 2002.

As a further robustness check, we instrument the change in the divided road stock within provincial boundaries with the stock of railroads as of 1945. In late 1920s, the early years of the Turkish Republic, there was an intense effort to construct new railroads with the goal of increasing the access to provinces with important natural resources such as coal and iron, and improving national security. Railroads constructed until 1945 had been planned in that era. During the 1923-1945 period, 5,500 km of new lines were built on top of the existing lines of 3,121 km from the pre-republic era. Investment in railroads slowed down after 1945 as only an annual average of 30 km railroads was constructed during the period 1950-1980.

The bottom panel of Figure 2 shows that there is considerable overlap between the newly constructed divided road network during the period 2003-2012 and the existing railroad network as of 1945. We believe that there are strong arguments for instrument validity: investments in railroads in the early to mid-20th century were primarily driven by the locations of natural resources and military considerations, which are not likely to causally affect recent trade flows. Railroad access is not likely to affect firm location decisions, which is reflected by the marginal role of railway transportation in our data period.[14]

In the first-step, we construct our road quality measure drs_{pg} using the share of railroad

[14] As of 2008, the freight share of railways (in ton-miles) is only 4 percent.

stock in in total road stock on the route pg:

$$drs_{pg}^{rail} \;=\; \frac{\sum_{j\in J_{pg};j\neq p} railroad_j}{\sum_{j\in J_{pg};j\neq p} total\_road_{j,2003}},$$

where $railroad_j$ is the length (in km) of the railroad stock in province j as of 1945. We use transport costs calculated using drs_{pg}^{rail} to instrument our transport cost variable in (7).

Table 5 presents the results we obtain from estimating long differences using the instrumental variables method. We consider the province-level as well as province-industry and province-destination level specifications. Our instrument passes the weak instrument test in all specifications. The results we obtain are even stronger compared to those obtained using OLS: the coefficient estimates of β are larger in absolute value, and they are significant at the 5 percent or 1 percent levels. These results increase our confidence in the qualitative results we obtain using OLS.

3.2 Transport Costs and Transportation Intensive Exports

Having documented the export-enhancing effect of expressway construction, we now explore a potential channel through which this increase may have materialized. As we argued in section 1, improved road transportation may have a bigger impact on trade in more transportation-intensive industries. Transportation-intensity of an industry may arise from its sensitivity to delivery times or heaviness of its output. For instance, in section 2, we provided external evidence that the median time it takes to transport goods from the point of origin to ports/airports in Turkey decreased from 2.5 days in 2007 to 2 days in 2012. One may expect such an improvement in export lead times to affect some industries more than others, depending on their time sensitivity.

Since our data inform us about the exports of each province in 24 industries over time, we would like to estimate the following relationship:

$$\ln(exp_{pit}) \;=\; \gamma Z_{pit} + \delta_a \cdot \ln(TC_{pt}) \times Air_i + \delta_h \cdot \ln(TC_{pt}) \times Heavy_i + \epsilon_{pit}, \tag{15}$$

where TC_{pt} is our province-level transport cost measure, Air_i is the air intensity of shipments in industry i, and $Heavy_i$ is the heaviness of the industry's output. After controlling for the effect of weight to value ratio, Air_i measures the time-sensitivity of an industry—air shipping is less suitable for goods with a high weight-to-value ratio (Harrigan 2010). Depending on the specification, Z_{pit} includes various other controls and fixed effects. If provinces with a higher decrease in trade costs experienced a larger increase in the exports of time-sensitive goods, the coefficient δ_a will be negative. Also we expect that industries with higher weight to value ratio to benefit more from an improvement in the quality of road infrastructure, i.e. δ_h will also be negative.

Our time-sensitivity measure is guided by the empirical literature investigating the mode of shipping decisions in international trade. As Hummels and Schaur (2013) demonstrate, exporters pay a premium for expensive yet fast air cargo, depending on the value that consumers attach to fast delivery. Motivated by this observation, we use the air share of industry i imports into a country other than Turkey. In particular, we use imports into the United Kingdom in 2005.[15] We define Air_i and $Heavy_i$ as follows:

$$Air_i = \frac{air\_val_i}{air\_val_i + ves\_val_i} \qquad , \qquad Heavy_i = \ln\left(\frac{ves\_wgt_i}{ves\_val_i}\right) \tag{16}$$

where air_val_i denotes the value of air shipments into the United Kingdom in industry i in 2005, and ves_val_i (ves_wgt_i) the value (weight) of shipments by ocean vessel. Table 6 reports both variables for all 24 industries.[16]

When estimating equation (15), we include province-year and province-industry fixed effects. Including the latter is particularly important as ignoring industry specialization of provinces might create bias in our estimates. Results are presented in the first three columns of table 7. The first column does not control for province-year fixed effects, thus our transport cost measure is still identified. Its coefficient estimate has the expected sign and is highly significant.

[15] We obtain similar results using US import data. To preserve space, we only report the results based on UK imports. Alternative results are available from the authors upon request.

[16] As expected, these two measures are negatively correlated. When we regress Air_i on $Heavy_i$, the coefficient is -0.158 with a t-statistic of -4.94. The R^2 is 0.53.

Its interaction with Air_i is also of the expected sign and significant at the 1 percent level. To understand the economic significance of our estimates, let us work through an example. Consider two provinces: one at the $90th$ percentile of the distribution of our transport cost measure, and the other at the $10th$ percentile. We are interested in how exports of these two provinces respond to a fall in transport costs in the most and the least time-sensitive industries. Our estimates suggest that the effect of time sensitivity is economically significant: a 1 percent decrease in transport costs increases exports of the more remote province relative to the less remote one by 2.9 percentage points more in the most time-sensitive industry compared to the least time-sensitive one.

In column 2, we include province-year fixed effects. The direct effect of the transport cost measure is not identified in this specification. The coefficient of the interaction term between the transport cost and the time-sensitivity measure remains highly significant both in the entire sample as well as in the subsample excluding the provinces with the trade gateways. The size of the coefficient estimate is also stable across different specifications. Results presented in table 7 suggest that heaviness also has a significant effect on the responsiveness of an industry's exports to a fall in transport costs, but its effect is smaller compared to time-sensitivity. Conditioning on destination, a fall in transport costs has a larger positive effect on exports of industries with higher weight to value ratio. Both interactions retain their significance when we estimate long differences as presented in column 3.

In our next specification, we use the full dimensionality of our data at the province-industry-destination-time ($pidt$) level:

$$\ln(exp_{pidt}) \;=\; \gamma Z_{pidt} + \delta_a \cdot \ln(TC_{pt}) \times Air_i + \delta_h \cdot \ln(TC_{pt}) \times Heavy_i + \epsilon_{pidt}. \qquad (17)$$

In columns 4 of table 7, we report the results from estimating equation (17) using destination GDP among the regressors to control for market demand. We add province-year fixed effects to control for any time-varying province characteristics, province-industry fixed effects to control for industry specialization of provinces, and province-destination fixed effects to control for the composition of exports from a province to a particular destination. Compared to the first three columns, the coefficient of the interaction term involving Air_i is larger in absolute value and highly significant at the 5 percent level.

In column 5 of table 7, we try to control for selection as missing province-destination exports might create bias in our estimates. Consider the case where transport costs for a province-destination pair are high, yet the province is exporting to the destination. Our specification in (17) implies that in such cases some unobserved factors included in ϵ_{pidt} correlate positively with our variable of interest, transport costs, creating a positive bias in our parameter of interest. In our data, more than 90 percent of zero export flows at the $pidt$ level are also zero at the province-destination-year (pdt) level. In other words, factors that we think might positively correlate with our transport cost measure could be varying at the province-destination-year level. To eliminate this potential bias, we benefit from the richness of our data and include province-destination-year fixed effects together with province-industry fixed effects in (17). In this specification, we rely on cross-industry variation to identify the interaction terms. Both interaction terms remain stable and highly significant in column 5 of table 7.

Next, we estimate the effect by taking log differences between the initial and terminal years in our dataset and present the results in column 6 of table 7. Province and destination fixed effects control for the general increase in exports due to regional supply and destination-specific demand factors. The magnitude of the interaction involving Air_i is consistent with the panel data estimates above and remains highly significant. The interaction with $Heavy_i$ also has the expected sign and is highly significant.

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 exports. While we argued that endogeneous selection is not a major concern in our setting, this claim can be made 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.

Finally, we present the relation between industries' estimated transportation intensity and their export growth during our data period. Since each industry has two characteristics, time sensitivity and heaviness, its transportation intensity can be calculated by factoring $\ln(TC_{pt})$ out of equation (17) and evaluating $\delta_a Air_i + \delta_h Heavy_i$ at the estimated $(\widehat{\delta}_a, \widehat{\delta}_h)$. For this exercise, we use the estimates from column 6 of table 7. To facilitate an intuitive comparison across industries, we take the negative of the average effect. In figure 5, we plot industries' export growth during our data period against their estimated transport intensity. The fit suggests that our transport intensity measure explains around 12% of the cross-industry variation in export growth during this period of rapid infrastructure buildup. Of course, the aggregate export response of an industry is also a function of its initial location: if transport intensive industries were initially agglomerated in provinces that had good market access to begin with (see figure 4), they would gain relatively little from transport cost reductions. Thus, the long term effect of the infrastructure investment could be more drastic if transport intensive industries endogenously locate towards the interior of the country, which now has better market access.

3.3 Transport Costs and Regional Specialization

In this final subsection, we investigate whether estimated responses in industry-level exports can be associated with regional employment and revenue reallocation across industries. We would expect provinces with increased exports in transportation-intensive industries to display a corresponding revenue increase in these industries. The responses of employment and wages are ambiguous and depend on labor mobility. If labor is geographically immobile (as in Kovak 2013) and industry-specific human capital plays a major role in production (as in Cosar 2013), we would expect relative wages in transportation-intensive industries to increase in provinces with increased exports of such industries. If, on the other hand, labor is somewhat mobile across industries and regions, the wage effect may be muted. In that case, we would expect to see increased regional employment in transportation-intensive industries.

In order to check these predictions, we supplement our dataset with information on industry employment, revenue, and wage bills at the NUTS 2 regional level obtained from TUIK. Unfortunately, such data are not available at the province level. Therefore, we average our transport cost measure across provinces within regions to obtain a regional transport cost measure. We then estimate a specification similar to equation (17) with the logarithm of industry-level regional employment $\ln(emp_{pit})$, revenue $\ln(rev_{pit})$, and average wage $\ln(wage_{pit})$ as dependent variables. As before, we expect the interaction coefficient to be negative. The first and last three columns of table 8 present the results from the estimation in levels and differences, respectively.

The results confirm our prediction of increased regional revenues in time-sensitive industries positively impacted by the investments in expressways (columns 2 and 5). The labor market effects suggest that labor is mobile enough to accommodate increased labor demand at the region-industry level: we see increased regional specialization in industries (columns 1 and 4) but fail to find an effect on average wages in columns 3 and 6. Results presented in table 8 suggest that heaviness of the industry does not matter for the effect of a fall in transport costs on regional outcomes.

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 lead to increased trade with regions whose connectivity to the international gateways of the country improved most. A 100-dollar investment on this infrastructure project implies an additional 10-year discounted stream of exports between 9 and 19 dollars. Given the additional benefits that we do not explore, this is a substantial return. 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 exports of transportation-intensive goods from regions that experience the largest drop in transport costs. In particular, time-sensitivity of an industry matters for the effect of transport costs on the industry-level exports. 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.

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Appendix: Figures and Tables

Figure 1: **Road Stock over Time: All Roads and Divided Roads**

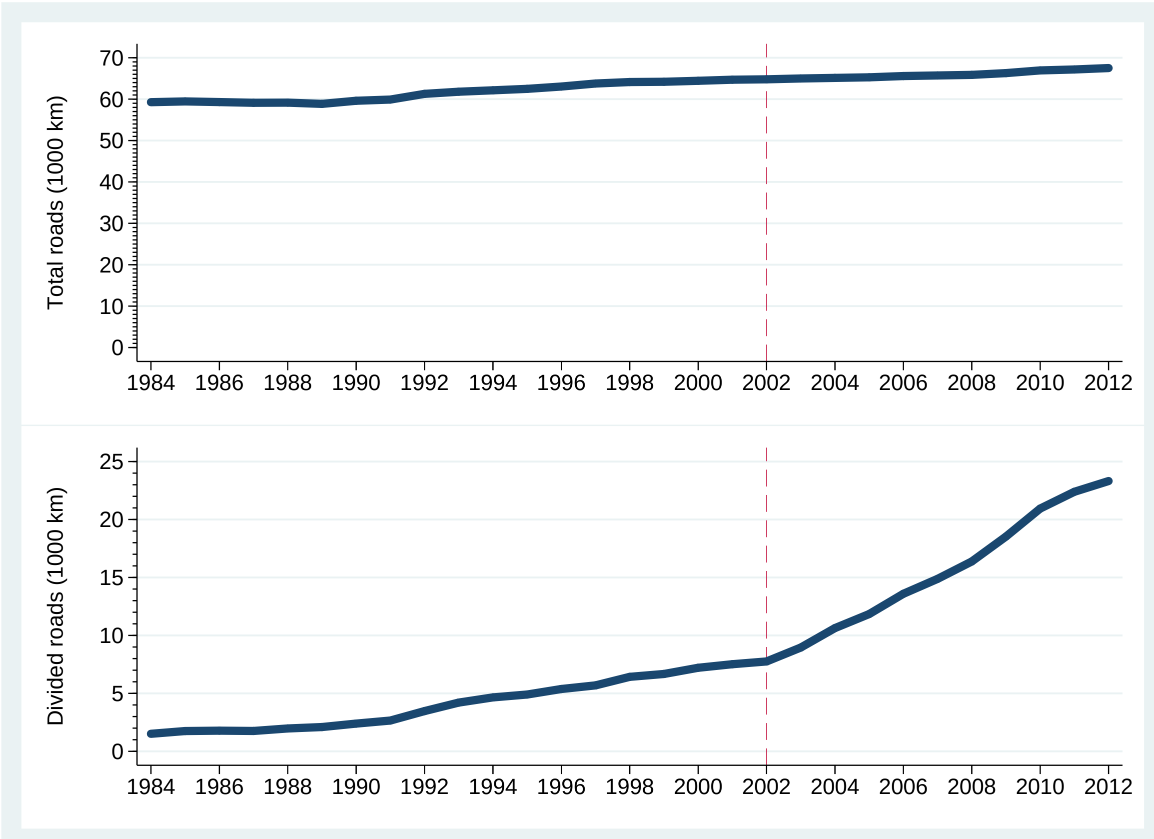
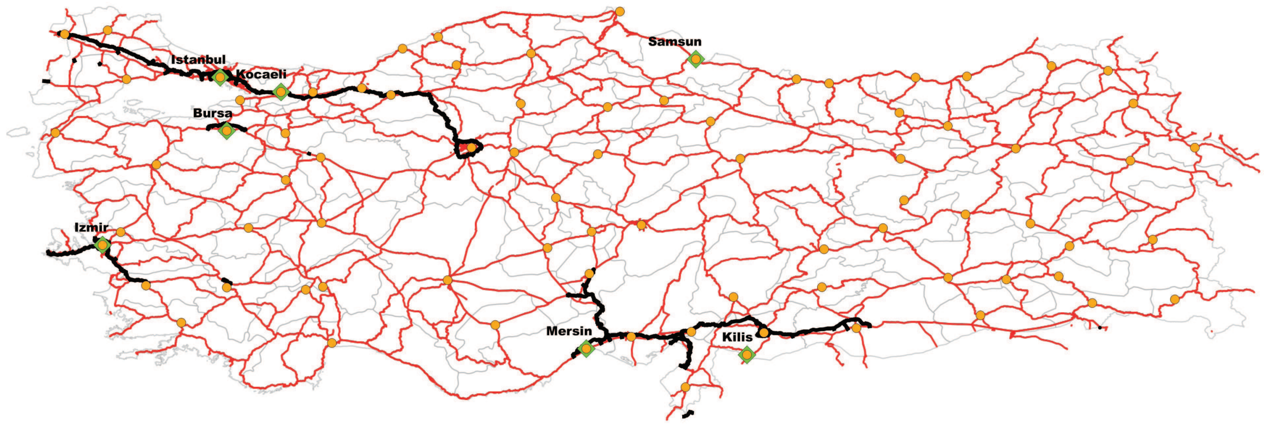
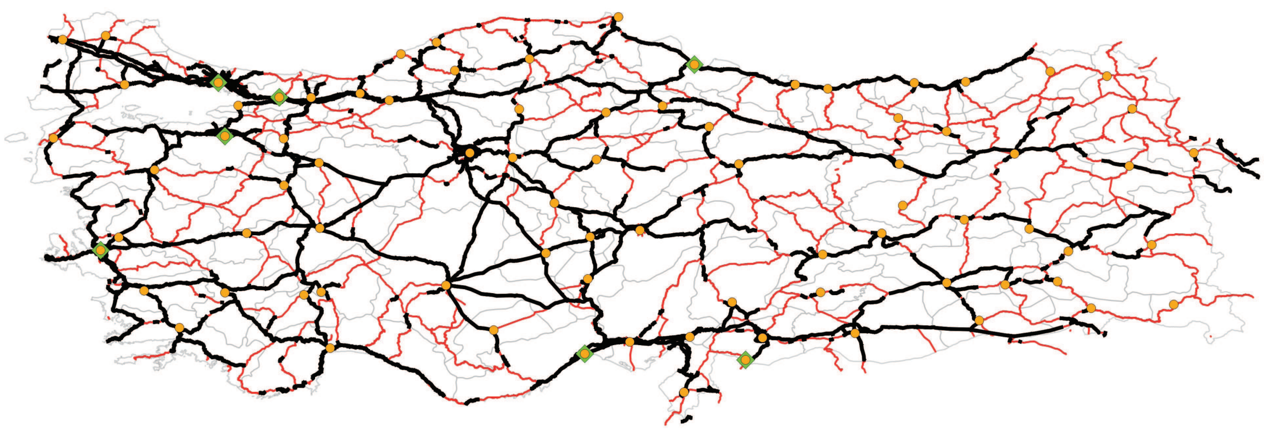


Figure 2: **Turkish Road and Railway Network**

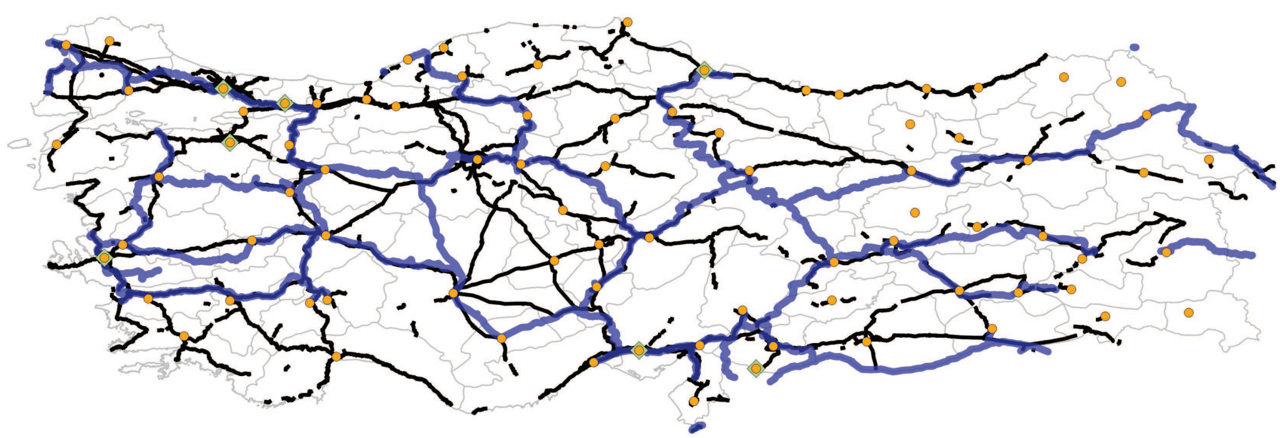
Road network in 2002



Road network in 2012

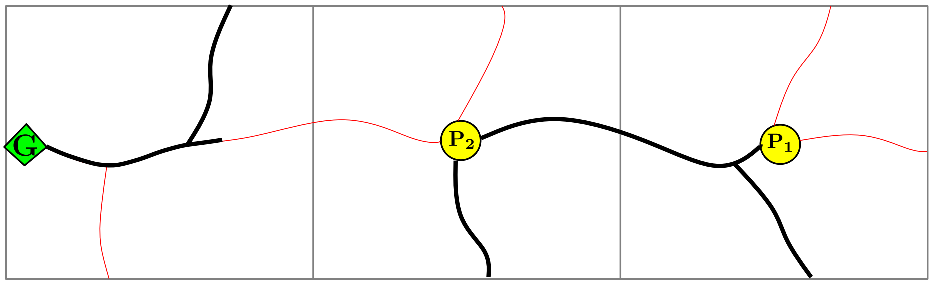


Railway network in 2002



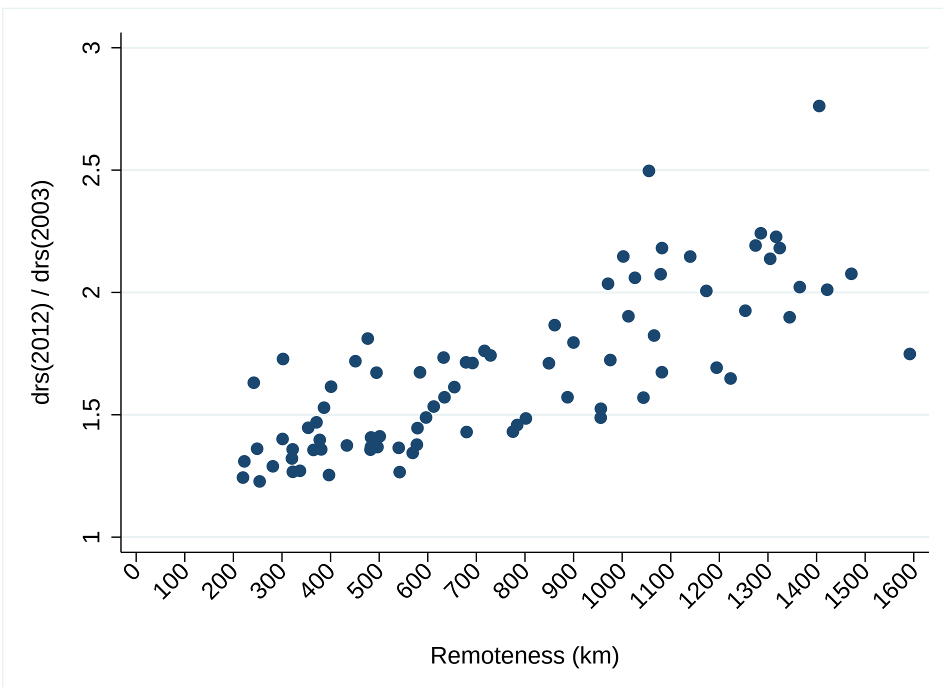
Notes: Red lines are standard roads, black lines are divided roads. Blue shaded lines in the bottom panel, overlaid on top of the divided road network, are railroads. Orange nodes are provincial centers, the ones with green diamond markers are centers of seven gateway provinces, which are labeled in the top panel. Gray boundaries are provincial borders. Geographical data used to plot the roads and railroads is downloaded from http://www.diva-gis.org. We checked its accuracy using official maps published by the General Directorate of Highways and found discrepancies only in a few segments. Since it is not official data, we did not use it in our analysis.

Figure 3: **Distance, Roads, and Divided Roads on a Route**



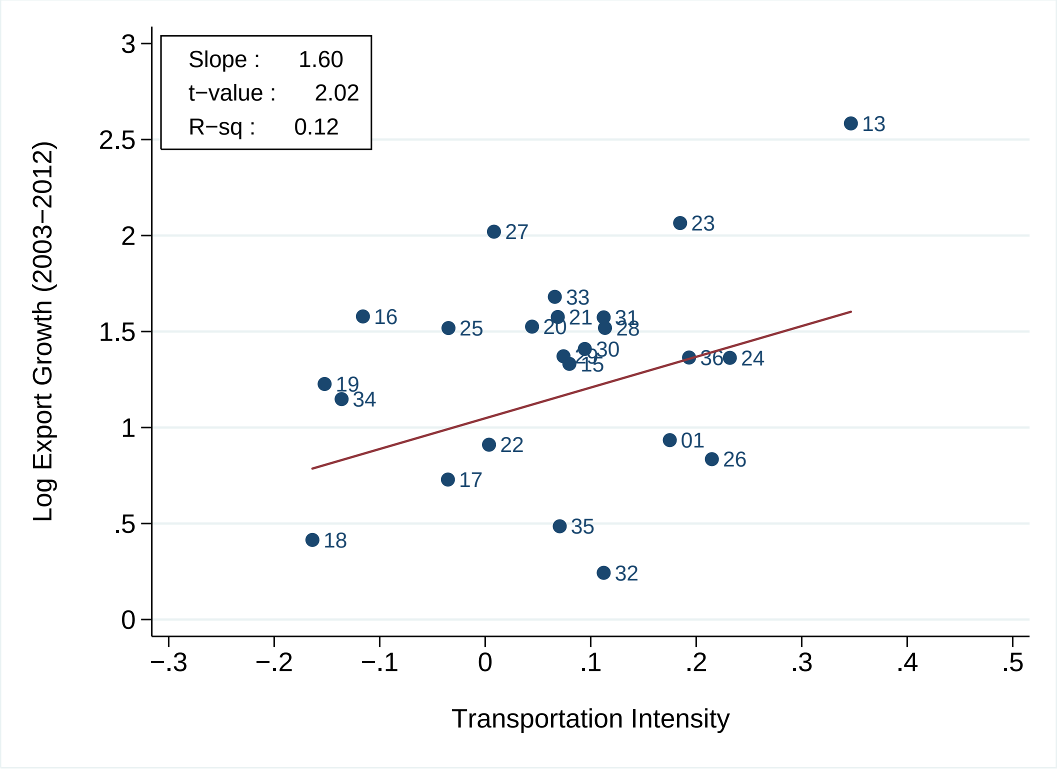
Notes: This illustration helps the description of the trade cost measure. See text for details. The shortest distance route from province P_1 to the gateway G passes through province P_2. Colors convey the same information as in the maps: red lines are standard roads and black lines are divided roads.

Figure 4: **Road Quality Improvements by Remoteness**



Notes: The x-axis is provinces' remoteness defined as $\sum_g ExpShr_{g,2002} \cdot dist_{pg}$, where $ExpShr_{g,2002}$ is the export share of gateway g in 2002 and $dist_{pg}$ is the distance between province p and gateway g. The y-axis is average divided road share on the routes from provinces to gateways in 2012 divided by its value in 2003. Precisely, let drs_{pgt} be the divided road share on the route between p and g in year t. Using the same 2002 export weights, find the average value for a province as $drs_{pt} = \sum_g ExpShr_{g,2002} \cdot drs_{pgt}$. The y-axis variable equals $drs_{p,2012}/drs_{p,2003}$, capturing the road quality improvement for a province in accessing foreign markets.

Figure 5: **Estimated Industry Transportation Intensity and Export Growth**



Notes: The x-axis is industry transportation intensity calculated as $\delta_a Air_i + \delta_h Heavy_i$ using the estimated coefficients from column 6 of table 7. The y-axis is the export growth of industries during the data period. The line is the weighted OLS regression fit with the weights equal to industries' 2003 export shares.

Table 1: **Road Quality and Distance Elasticity of Transport Costs**

	(1) $\Delta\ln(trade_p)$	(2) $\Delta\ln(exp_p)$	(3) $\Delta\ln(imp_p)$
$\tau = \tau_{old} - \tau_{new}$	0.253**	0.274***	0.162
	(0.112)	(0.093)	(0.099)
Regression	NLS	NLS	NLS
Robust SE	Yes	Yes	Yes
N	80	79	80
R^2	0.068	0.090	0.031

Notes: All regressions are estimated with non-linear least squares (NLS) using province populations as weights. Δ's indicate long-term differences between 2012 and 2003. Standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 2: **Road Quality and Distance Elasticity: Linear Results**

	(1) $\ln(trade_{pt})$	(2) $\ln(exp_{pt})$	(3) $\ln(imp_{pt})$	(4) $\Delta\ln(trade_p)$	(5) $\Delta\ln(exp_p)$	(6) $\Delta\ln(imp_p)$
$\ln(TC_{pt})$	-0.767***	-0.685***	-0.712***			
	(0.201)	(0.235)	(0.216)			
$\Delta\ln(TC_p)$				-0.823*	-0.721*	-0.484
				(0.486)	(0.381)	(0.378)
Initial Share				-0.705***	-0.864***	-0.484***
				(0.155)	(0.178)	(0.142)
Trend				0.253	-0.076	-0.051
				(0.268)	(0.149)	(0.155)
Regression	WLS	WLS	WLS	WLS	WLS	WLS
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes
N	808	803	807	80	79	80
R^2	0.990	0.983	0.989	0.135	0.140	0.065
Year FE	Yes	Yes	Yes			
Province FE	Yes	Yes	Yes			

Notes: All regressions are estimated with weighted least squares (WLS) using province populations as weights. Initial Share is provinces' share in total trade (or exports, imports depending on the column) in 2002. Trend is the percentage increase in the dependent variable between 1996-2000. Δ's indicate long-term differences between 2012 and 2003. Standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 3: **Extensive and Intensive Margins**

	(1) $\ln(ndest_{pt})$	(2) $\ln(nfirm_{pt})$	(3) $\ln(int_{pt})$	(4) $\Delta\ln(ndest_p)$	(5) $\Delta\ln(nfirm_p)$	(6) $\Delta\ln(int_{pt})$
$\ln(TC_{pt})$	-0.463***	0.003	-0.267			
	(0.0810)	(0.0864)	(0.170)			
$\Delta\ln(TC_p)$				-0.374***	0.103	-1.563
				(0.184)	(0.213)	(0.157)
Initial Share				-0.433***	-0.323***	-0.065
				(0.0710)	(0.096)	(0.253)
Trend				0.037	0.018	0.619
				(0.055)	(0.075)	(0.444)
Regression	WLS	WLS	WLS	WLS	WLS	WLS
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes
N	803	803	803	79	79	79
R^2	0.974	0.997	0.840	0.272	0.050	0.257
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Initial Share is provinces' share in total exports in 2002. Trend is the percentage increase in the dependent variable between 1996-2000. Δ's indicate long-term differences between 2012 and 2003. Intensive margin dependent variable in the 3rd and 6th columns is defined as $\ln[(exp_{pt})/(ndest_{pt} \cdot nfirm_{pt})]$. Standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 4: **Controlling for Industry and Destination Demand Effects**

	(1) $\ln(exp_{pit})$	(2) $\Delta\ln(exp_{pi})$	(3) $\ln(exp_{pdt})$	(4) $\Delta\ln(exp_{pd})$
$\ln(TC_{pt})$	-0.906***		-0.423**	
	(0.247)		(0.156)	
$\Delta\ln(TC_p)$		-1.637**		-0.889*
		(0.620)		(0.477)
Initial Share		-1.389***		-1.181***
		(0.355)		(0.218)
Trend		0.062		0.107
		(0.136)		(0.103)
Regression	WLS	WLS	WLS	WLS
Clustering	Industry	Industry	Destination	Destination
N	14,416	1,592	52,580	5,294
R^2	0.806	0.114	0.820	0.208
Province FE	Yes		Yes	
Industry FE		Yes		
Destination FE				Yes
Industry-Year FE	Yes			
Destination-Year FE			Yes	

Notes: Initial Share is provinces' share in total exports in 2002. Trend is the percentage increase in the dependent variable between 1996-2000. Δ's indicate long-term differences between 2012 and 2003. Standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 5: **IV Results**

	(1) $\Delta \ln(trade_p)$	(2) $\Delta \ln(exp_p)$	(3) $\Delta \ln(imp_p)$	(4) $\Delta \ln(exp_{pi})$	(5) $\Delta \ln(exp_{pd})$
$\Delta \ln(TC_p)$	-2.305**	-2.671**	-0.922	-3.122***	-4.830***
	(1.050)	(1.137)	(0.791)	(0.970)	(1.398)
Trend	0.289	0.068	-0.023	0.170	0.546***
	(0.282)	(0.165)	(0.199)	(0.127)	(0.161)
Initial Share	-0.278	-0.272	-0.391*		
	(0.262)	(0.312)	(0.235)		
Clustering	Robust SE	Robust SE	Robust SE	Industry	Destination
N	80	79	80	1,592	4,496
Industry FE				Yes	
Province FE					Yes
First-stage F-statistics	20.55	20.62	21.08	4595.76	1818.12

Notes: All regressions are estimated with two-stage least squares using province populations as weights. The instrumental variable is the trade cost measure constructed using the railroad network. Initial Share is provinces' share in total exports in 2002. Trend is the percentage increase in the dependent variable between 1996-2000. Δ's indicate long-term differences between 2012 and 2003. First-stage F-statistics is Angrist-Pischke multivariate F-test statistic. Standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 6: **Air Shares and Heaviness of Industries**

ISIC Rev.3	**Industry**	Air_i	$Heavy_i$
01	Agriculture, hunting and related	0.994	-2.813
35	Other transport equipment	0.901	-3.255
33	Medical, precision and optical instruments, watches, and clocks	0.777	-2.764
31	Electrical machinery and apparatus n.e.c.	0.675	-1.962
32	Radio, television and communication equipment and apparatus	0.675	-1.962
36	Furniture; manufacturing n.e.c.	0.656	-1.236
30	Office, accounting and computing machinery	0.637	-1.944
29	Machinery and equipment n.e.c.	0.604	-1.966
24	Chemicals and chemical products	0.540	-0.436
28	Fabricated metal products, except machinery and equipment	0.466	-1.066
22	Publishing, printing and reproduction of recorded media	0.327	-1.357
18	Wearing apparel; dressing and dyeing of fur	0.232	-2.296
19	Leather; manufacture of luggage, handbags, footwear	0.185	-2.003
17	Textiles	0.165	-0.981
25	Rubber and plastics products	0.119	-0.784
34	Motor vehicles, trailers and semi-trailers	0.117	-1.586
26	Other non-metallic mineral products	0.103	1.281
13	Mining of metal ores	0.083	2.422
15	Food products and beverages	0.082	0.292
27	Basic metals	0.073	-0.244
16	Tobacco products	0.065	-1.203
21	Paper and paper products	0.058	0.307
20	Wood and products of wood, except furniture	0.018	0.278
23	Coke, refined petroleum products and nuclear fuel	0.002	1.472

Notes: Air_i and $Heavy_i$ stand for air share and heaviness of industry-level imports into the United Kingdom 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.

Table 7: **Industry Transportation Intensity and Exports**

	(1) $\ln(exp_{pit})$	(2) $\ln(exp_{pit})$	(3) $\Delta\ln(exp_{pi})$	(4) $\ln(exp_{pidt})$	(5) $\ln(exp_{pidt})$	(6) $\Delta\ln(exp_{pid})$
$\ln(TC_{pt})$	-1.252***					
	(0.0500)					
$\ln(TC_{pt}) \times Air_i$	-0.516***	-0.529***		-0.588***	-0.638***	
	(0.135)	(0.140)		(0.0848)	(0.0929)	
$\ln(TC_{pt}) \times Heavy_i$	-0.101***	-0.122***		-0.146***	-0.162***	
	(0.0363)	(0.0377)		(0.0186)	(0.0209)	
$\Delta\ln(TC_{pt}) \times Air_i$			-0.596**			-0.530***
			(0.249)			(0.166)
$\Delta\ln(TC_{pt}) \times Heavy_i$			-0.148**			-0.125***
			(0.0695)			(0.0448)
Regression	OLS	OLS	OLS	OLS	OLS	OLS
Clustering	Prov.-Year	Prov.-Year	Province	Prov.-Year	Prov.-Year	Province
N	14,416	14,416	1,271	272,170	272,170	24,704
R^2	0.878	0.892	0.139	0.574	0.628	0.068
Province FE			Yes			Yes
Province-Year FE		Yes		Yes		
Province-Ind. FE	Yes	Yes		Yes	Yes	
Province-Dest. FE				Yes		
Province-Dest.-Year FE					Yes	
Destination FE						Yes

Notes: Columns 4 controls for destination GDP. Standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.

Table 8: **Additional Regional Outcomes**

	(1) $\ln(emp_{pit})$	(2) $\ln(rev_{pit})$	(3) $\ln(wage_{pit})$	(4) $\Delta d\ln(emp_{pi})$	(5) $\Delta\ln(rev_{pi})$	(6) $\Delta\ln(wage_{pi})$
$\ln(TC_{pt}) \times Air_i$	-3.257***	-3.084***	0.201			
	(0.380)	(0.332)	(0.284)			
$\ln(TC_{pt}) \times Heavy_i$	-0.450***	-0.105	0.0846			
	(0.121)	(0.0868)	(0.0545)			
$\Delta\ln(TC_p) \times Air_i$				-2.475***	-1.902***	0.190
				(0.437)	(0.367)	(0.481)
$\Delta\ln(TC_p) \times Heavy_i$				-0.157	0.145	0.0627
				(0.201)	(0.184)	(0.0929)
Regression	WLS	WLS	WLS	WLS	WLS	WLS
Clustering	Region-Year	Region-Year	Region-Year	Region	Region	Region
N	3160	3028	2494	350	323	299
R^2	0.803	0.842	0.718	0.126	0.116	0.122
Region-Year FE	Yes	Yes	Yes			
Region-Industry FE	Yes	Yes	Yes			
Region FE				Yes	Yes	Yes

Notes: All regressions are estimated with weighted least squares (WLS) using regional populations as weights. Standard errors in parentheses. Significance: * 10 percent, ** 5 percent, *** 1 percent.