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Abstract[♦]

Our knowledge of the trade effects of domestic infrastructure is very limited. The reason is twofold. First, data needed to examine these effects are not readily available. Second, identifying such effects requires properly addressing potential endogeneity problems affecting the relationship between internal infrastructure and trade. In this paper, we overcome these limitations by combining firm-level data with detailed geo-referenced information on Chile and by exploiting the earthquake that took place in this country in 2010 as an exogenous source of variation in available infrastructure and thereby in transport costs. We find that diminished transportation infrastructure had a significant negative impact on firms' exports.

Keyword: Firms, Transport Infrastructure, Exports, Chile

JEL Code: F10, F14, D22, H54, R40, C25

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1. Introduction

Products from the top 10% Chilean manufacturing firms in terms of distance from plants to exiting ports must be shipped more than 1,000 kilometers.[1] While these might *a priori* appear as extreme cases, situations in which within-country transport costs represent a significant portion of total transport costs incurred in international trade transactions are far from being the exception. In fact, it has been shown that domestic freight costs accounted for 36.6% of international transport costs in the United States a few decades ago (see Rousslang and To, 1993).[2] This suggests that internal transport infrastructure and hence internal transport costs can be important determinants of trade. However, available evidence on to what extent this infrastructure actually matters for exporting is at most very limited. The reason is twofold. First, data needed to rigorously examine the effects of domestic infrastructure on trade are not readily available. Second, properly identifying such effects requires to successfully addressing potential endogeneity problems affecting the relationship between infrastructure and trade. In this paper, we aim at filing this gap in the empirical literature by overcoming the data limitations and implementing a convincing identification strategy. In particular, we combine highly disaggregated firm-level trade data with detailed geo-referenced information on Chile and exploit the earthquake that took place in this country in 2010 as an exogenous source of variation in infrastructure and accordingly in transport costs.

Assessing the impact of domestic transport infrastructure on trade is data demanding. Thus, in order to accurately measure this variable, one needs information on the geographical origin of the exports, the points through which the goods leave the country, and the existing road network.[3] Hence, researchers have been typically forced to work with more or less partial proxies, such as road distance to the nearest most used exit node (see, e.g., Matthee and Naudé, 2008; and Granato, 2008) or to the international border with the main trading partner (see, e.g.,

[1] Thus, for instance, Cervecería Austral is a Chilean brewery located in the city of Punta Arenas-only 1,120 kilometers from the Antarctic continent. This company founded in 1896 chose to establish the brewery in this city, next to a lagoon that remained frozen for several months, because this allowed for extraction of large blocks of ice that served as a cooler, thus providing a cheap cooling system at that time. The firm exports to various countries, including Mexico and France. To do so, it must first ship the beer to the San Antonio port more than 3,000 kilometers away, and partially through another country, Argentina, as there is no land route within the Chilean border from Punta Arena all the way to that port. Remarkably, the distance traveled along domestic routes from the plant to the port accounts for 30% and 18%, respectively, of the total distance to the destination ports in the aforementioned countries.

[2] Using the US Commodity Flow Survey, Hillberry and Hummels (2008) investigate how the intra-national trade components co-vary with spatial frictions. They find that the number of shipments and the number of unique establishments-destinations decrease pronouncedly with distance.

[3] Further, in order to compute actual transport costs, one needs access to the (time-varying) cost factors to calculate the associated distance- and time-related costs that add up to the total transport cost incurred within the country.

Costa-Campi and Viladecans-Marsal, 1999), the shortest travel time to the main seaports (see, e.g., Albarrán et al., 2009), binary variables capturing the presence of an airport or a port in the origin region (see, e.g., Costa-Campi and Viladecans-Marsal, 1999), and regional transport infrastructure density (see, e.g., Nicolini, 2003). Evidence based on these crude approximations of available transport infrastructure, and thus of the actual costs of moving goods within countries, consistently indicates that this infrastructure have a significant effect on exports.

A second important challenge that empirical attempts to quantify this effect are confronted with is to find an identifying strategy that satisfactorily addresses the potential endogeneity between infrastructure and trade. Thus, road improvements might be thought to favor better export performance of benefited regions, but is also equally possible that growing exports lead to transport cost-reducing investments in these regions. While certainly valuable, most existing studies do not convincingly tackle this problem, and not doing so is likely to result in biased estimates of the effect of interest.[4]

In this paper we use a natural experiment to identify the effects of domestic transport infrastructure on firms' exports. In particular, we exploit the random and exogenous variation in this infrastructure associated with the earthquake that took place in Chile in February of 2010. This earthquake damaged certain sections of the road network but not others. As a consequence, depending on the route(s) from the plants to the ports, airports or borders used in exiting the country, available transport infrastructure diminished thereby increasing internal transport costs for some exports while those for others remained the same. Hence, by contrasting exports in both groups while controlling for potential confounding factors, we can consistently estimate the impact of infrastructure on firms' exports. More precisely, we perform difference-in-differences estimations on highly disaggregated firm-level data that inform the exact geographical origin of the exports and the location of the customs through which the exports exit the country. We therefore compare the before and after change in exports whose pre-earthquake routes -as determined by a methodology that combines freight costs and Geographic Information System (GIS) analysis- were later affected by this event with those whose routes did not suffer any damage. Admittedly, this clean strategy has non-neutral implications in terms of the kinds of

[4] The analysis carried out by Albarrán et al. (2009) is one of the few exceptions in this regard. These authors use the dynamic GMM estimator proposed by Blundell and Bond (1998) to estimate the impact of the road travel time to the main seaports on the probability to export. This analysis, however, has a major limitation. The location of the companies whose export decisions are being examined are only known at an aggregated level (i.e., region instead of municipality) and hence in a relatively imprecise manner.

effects that can be identified. Given this strategy and our sample period (February 2009-February 2011), the estimates reported below are mainly capturing the immediate, short run export response to a temporarily disruption in transport infrastructure rather than the long-run export response to a permanent infrastructure shock.

Second, in our case, the exclusion restriction might be potentially violated. Thus, firm exports may have been negatively affected by the earthquake through channels other than road infrastructure, such as, for instance, direct damages of production facilities or of sources of energy provision. Given that this has occurred in some regions, we carefully address this concern in our robustness check exercises by removing from our sample, among others, those firms that –according to official data- experienced limitations in their production capacity and by directly excluding those located in regions closest to the epicenter of the earthquake altogether.

We find that diminished domestic transport infrastructure translated into a strong negative impact on firm export values and quantities. This impact primarily originates from a reduction in the number of shipments. The evidence further suggests that exports of more homogeneous goods from large firms could have been particularly affected.

Our analysis contributes to at least four different literatures. First, by using a natural experiment, this analysis adds to a series of recent papers that seriously account for potential endogeneity when assessing the effects of infrastructure, both within countries (see, e.g., Fernald, 1999; Baum-Snow, 2007; Michaels, 2008 and Donaldson, 2010) and across countries (see, e.g., Feyer, 2009; Akerman, 2009; and Volpe Martincus et al., 2012), on economic outcomes.[5] More specifically, our study is –to our knowledge- the first one to take this approach to examine how domestic transport infrastructure and hence transport costs affect firm exports. Second, it thereby complements a number of studies showing that international transport costs, in general, and port inefficiency, in particular, have a significant negative impact on trade (see, e.g., Hummels, 2001;

[5] Fernald (1999) estimates the impact of roads on productivity growth across industries with different vehicle intensity in the United States based on a non-linear regression equation that combines aggregate and sectorally disaggregated data to get rid of an omitted-variable driven-endogeneity problem. Baum-Snow (2007) and Michaels (2008) use, among others, plans for the US Interstate Highway System –that were designed to strengthen national defense and improve connectivity among major metropolitan areas and with Canada and Mexico- as instruments for the actual highways to examine their effects on suburbanization and relative demand for skilled workers, respectively. Duranton and Turner (2008) consider a similar instrument and a second one derived from historical data on the railroad network to analyze the effects of major roads and public transportation on the growth of major US cities. Donalson (2010) explores the impact of the construction of India's railroad network on price gaps, interregional and international trade, and real income levels. In so doing, he exploits the facts that the placement of most involved projects was primarily driven by military reasons and that the networked nature of railroad technology did not allow for targeting of specific locations and uses approved construction plans that were never actually built as placebos. Finally, Feyer (2009), Akerman (2009), and Volpe Martincus et al. (2011) take the closing of the Suez Canal, the construction of the bridge on the Öresund Straight, and the environmentally-related blockade of the main bridge connecting Argentina and Uruguay, as natural experiments to investigate how international transport costs affect trade, respectively.

Limão, and Venables, 2001; Clark et al., 2004; Blonigen and Wilson, 2008; and Mesquita Moreira et al., 2008). Third, given the type of natural experiment it looks at, our paper also contributes to the incipient literature on the economic consequences of natural disasters (see, e.g., Raddatz, 2007, 2009; Skidmore and Toya, 2007; Noy, 2009; Gassebner et al., 2010; and Cavallo et al., 2010). In particular, it sheds new light on the trade channel of these macroeconomic effects. Fourth, our results reveal new facts about the –essentially short run- impacts of internal transport infrastructure on firms' exports and provide insights on the specific mechanisms through which these effects can arise, thus extending the empirical literature on trade and heterogeneous firms and potentially helping foster additional theoretical developments in this area.[6]

The remainder of this paper is organized as follows. Section 2 discusses the road infrastructure consequences of the 2010 Chilean earthquake and makes the case of using this event as a valid identification strategy. Section 3 explains the empirical approach. Section 4 describes the datasets and presents basic statistics. Section 5 reports the estimation results, and Section 6 concludes.

2. The Chilean Earthquake as a Natural Experiment

On February 27, 2010 an earthquake with a magnitude of 8.8 in the Ritcher's scale took place in Chile, being the eighth strongest one ever measured. The epicenter was located about 330 kilometers southwest of Santiago -the capital of the country- and about 105 kilometers from Concepción -the second largest city. It was strongly felt in six out of the 15 regions, which together account for more than 70% of country's population.

The earthquake caused several damages to the road network. According to Chile's ministry of infrastructure -*Ministerio de Obras Públicas* (MOP)-, 717 points of the public road network were affected, including 396 roads and highways, 90 access roads, and 212 bridges (see MOP, 2010a). In addition, 62 points of the road network under private concessions also registered damages. In total, the MOP estimated that 1,554 kilometers were somewhat affected by the earthquake, i.e., roughly 9% of the total paved road network. The various incidents ranged from

[6] From a methodological point of view, our paper illustrates how GIS techniques that have been applied elsewhere (see, e.g., Combes and Lafourcade, 2005) can also be a helpful tool in international trade studies.

mud slides on the side of the road, which lead to instructions for cautiously transit, to complete collapses of bridges, which directly impeded circulation. Figure 1 shows Chile's entire (primary and secondary) road network along with a zooming on the area where the 55 points with complete traffic interruption were located. Repairing and reconstruction took several months and was not finished until very recently. Thus, four months after the earthquake only 14% of the affected road network had been completely recovered (see CCHC, 2010). Two months later, almost 30% of the points of the road infrastructure that suffered from damages were still not in full operation (see MOP, 2010a). As of February, 2011, 20 bridges and more than 30 roads and access roads continued to cause partial restrictions on transit (see MOP, 2011).

Importantly, Figure 1 reveals that, while many roads were damaged by the earthquake, several of them remained unaffected. Thus, depending on the route(s) optimally chosen in the absence of restrictions on the road infrastructure to ship the product from the plant to the exit point, firms may have been forced or not to detour through alternative routes.

Assuming that profit-maximizing firms have incentives to select the least-cost route between any two shipping locations, the domestic route(s) that each firm originally used from the production facilities to the exiting customs in shipping each of their products to each of their destination countries can be identified applying a methodology that combines spatially geo-referenced data on the road network with truck operating costs (see Combes and Lafourcade, 2005).[7] As mentioned above, some of these routes became impassable.[8] These roads can be accurately determined using detailed information provided by the MOP, which includes the exact geo-referenced location and the description of each incident. Shipments previously made through these routes had to be rerouted to alternative ones, which can in turn be identified with the method referred to previously. As a consequence of such detours, these firms' goods must be shipped over longer distances to reach their original port or directly to new, more distant ones.[9] This can be clearly seen in Figure 2, which shows the distribution of distances traveled between production plants and exit nodes before the earthquake against that after this event along with a kernel density estimate of the distribution of the ratio of associated post- to pre-earthquake transport costs. These figures reveal that the negative shock to the road infrastructure caused an

[7] The methodology is explained in detail in the Appendix.
[8] This corresponds to those incidents in which a total traffic interruption was the consequence.
[9] Approximately, 35% of the exports with damaged roads in our sample registered changes in the number of their exiting ports between 2009 and 2010. However, this is not confined to these exports, as comparable port shifting, i.e., 28%, also occurred among exports whose routes were not affected.

important shifting in the distribution of distances, which translated into higher transport costs. In particular, the median cost ratio is 1.3, thus suggesting that the median increase of these costs was approximately 30%.

Hence, firm-product-destinations whose typical routes were damaged had to reroute, thus experiencing diminished domestic transport infrastructure and thereby increased transport costs, where their counterparts using non-affected routes continued doing so without facing changes in their available transport infrastructure and the transport costs incurred in. This *a priori* provides us with a random and exogenous variation in infrastructure and thereby in transport costs that can be used to identify their causal effects on firms' exports.

An obvious challenge to this identification strategy comes from the exclusion restriction. We can conceivably think that the earthquake may have affected firms' exports through channels other than the damages to road infrastructure. Thus, for instance, this natural disaster may have induced disruptions in production either directly through destruction of facilities or indirectly through electrical outages derived from reduced energy generation and/or distribution. In addressing this concern, we primarily rely on a baseline estimating export equation that includes firm fixed effects and thus in principle allows us to account for firm-level production shocks. Fortunately, in addition, we are able to precisely identify and exclude those companies that experienced substantial production losses as a result of the earthquake, thus reasonably ruling out potential violations of the aforementioned restriction. This is possible thanks to detailed plant-level information that has been gathered by Chile's statistical office *–Instituto Nacional de Estadísticas* (INE)- while carrying out its monthly production and sales survey, and that this office has kindly shared with us. Second, and more generally, surveys from relevant public entities and representatives business associations such as the federation of Chilean industry –*Sociedad de Fomento Fabril* (SOFOFA)- and the association of manufacturing and services exporters –*Asociación de Exportadores de Manufacturas y Servicios* (ASEXMA)- indicate that damages to plants and electrical outages were virtually entirely confined to three districts—Concepción, Coronel, and Talcahuano--, which are very close to the epicenter of the earthquake. We therefore also adopt a more conservative approach and simply remove firms located in these districts altogether from our sample. In the analysis below we thus explore the sensitivity of the estimates to these restrictions on the sample. We next explain the empirical methodology on which this analysis is based.

3. Empirical Methodology

We aim at estimating the effects of domestic transport infrastructure on firms' exports. As mentioned above, in this paper we rely on the exogenous variation in this infrastructure induced by an earthquake to identify such an effect. Clearly, factors other infrastructure may have affected firms' exports. Thus, these may have decreased because reduced firm productivity or lower demand for their products. Failure to properly account for these other factors would result in biased impact estimates. A possible strategy to isolate these potential confounders consists of using disaggregated export data and including appropriate sets of fixed effects in the equation estimated on these data (see, e.g., Paravisini et al., 2011). We adopt this approach here. In particular, our empirical model of exports is as follows:

$$lnX_{fpct} = \alpha D_{fpct} + \lambda_{fpc} + \delta_{ft} + \rho_{pct} + \varepsilon_{fpct} \quad (1)$$

where f denotes firm, p stands for product, c indicates country, and t indexes time. The main variables are X and D. The former represents export value. The latter is a binary indicator that takes the value of one if the domestic routes that firm f originally used to ship product p to country c were affected by the earthquake at time t and 0 if none of the routes were damaged. In our baseline estimations, the indicator variable D takes the value of one if at least one of the export's routes were damaged by the natural disaster. The coefficient on this variable, α, is accordingly our parameter of interest. If $\alpha < 0$ ($\alpha = 0$), then rerouting due to diminished road infrastructure has had a negative (no) impact on exports. The remaining terms of Equation (1) correspond to control variables. Thus, λ_{fpc} is a set of firm-product-country fixed effects that captures, for instance, the firm knowledge of the market for a given product in a given country; δ_{ft} is a set of firm-year fixed effects that accounts for firm-level production shocks, time-varying firm characteristics, and overall performance (i.e., productivity); ρ_{pct} is a set of product-country fixed effects that controls for product-destination shocks such as changes in tariffs applied on products across importing countries, specific variations in international transport costs, and fluctuations in demand for goods across markets; and ε is the error term.

In estimating Equation (1), we use first-differencing to eliminate the firm-product-country fixed effects.[10] Further, we aggregate time series information into two periods around the

[10] When the number of periods is equal to two, first-differencing and fixed effect estimation produce identical estimates and inference (see Wooldridge, 2002).

earthquake ($s = 0$ and $s = 1$), i.e., one year before (February 27, 2009-February 26, 2010) and one year after (February 27, 2010-February 26, 2011) the occurrence of this event. In so doing, we address the serial correlation problem to which equations such as ours are typically subject (see Bertrand et al., 2004). We therefore estimate the following baseline equation:

$$\Delta lnX_{fpc1} = \alpha D_{fpc1} + \delta'_f + \rho'_{pc} + \varepsilon'_{fpc} \quad (2)$$

where we already have taken into account that $\Delta D_{fpc1} = D_{fpc1}$because no routes suffered from damages in the initial period (i.e., $D_{fpc0} = 0 \ \forall fpc$); $\delta'_f = \delta_{f1} - \delta_{f0}$ accounts for firm heterogeneity; $\rho'_{pc} = \rho_{pc1} - \rho_{pc0}$ absorbs all product-country shocks; and $\varepsilon'_{fpc} = \varepsilon_{fpc1} - \varepsilon_{fpc0}$.

Notice that we are essentially using a difference-in-difference estimator, whereby the before and after change in exports whose routes were not affected by the earthquake serves as an estimate of the counterfactual for those exports whose routes were damaged. By comparing these changes, the difference-in-differences estimator permits controlling for observed and unobserved time-invariant factors as well as time-varying ones common to both treated and comparison groups that might be correlated with being exposed to the negative infrastructure shock and exports (see, e.g., Galiani et al., 2008). Equation (2) additionally includes covariates that account for systematic differences across firms and product-destination shocks, thus substantially reducing the risk of omitted variable biases and particularly of heterogeneity in export dynamics.

The baseline equation assumes that the effect of transport infrastructure on exports is symmetric across firms and products. There are, however, reasons to believe that these effects may differ among groups of companies and goods, in which case such a restriction would not hold. Thus, larger firms use more intensively the road infrastructure and are accordingly more likely to have been confronted with binding transport constraints and they may be more sensitive to the implied change in trade costs in a range of their several destination markets (see, e.g. Lawless, 2009). On the other hand, these firms might be thought to have been in a better position to negotiate relatively smaller increases in domestic freight rates with truck companies or logistic operators. Similarly, exports of differentiated goods may be less responsive to increases in transport costs associated with diminutions in domestic infrastructure than those of more homogeneous goods because either their lower demand elasticity makes it easier to forward the higher costs onto buyers or their larger markups facilitate cost absorption. Hence, we also generalize this equation to explore the existence of heterogeneous effects across those groups as follows:

$$\Delta lnX_{fpc1} = \sum_{i=1}^{I} \alpha_i \Theta_i D_{fpc1} + \delta'_f + \rho'_{pc} + \varepsilon'_{fpc} \quad (3)$$

where i indexes the groups of firms (small and large), products (differentiated and non-differentiated), and their combinations; and Θ is the corresponding binary group indicator.[11]

4. Data and Descriptive Statistics

Our dataset consists of two main databases. We have transaction-level data from the Chilean national customs authority -*Servicio Nacional de Aduanas*- for all manufacturing firms over the period February 2008-February 2011. Specifically, each record includes a firm identifier, the location of the plant (*comuna*), the good shipped (at a 8-digit HS level), the port, airport or land border through which the good exits Chile, the destination country, the export value in US dollars, and the quantity (weight) in kilograms.[12] Hence, for each manufacturing firm, we know the geographical origin of their exports, the export value, the quantity shipped, the number of shipments, and the exiting customs for each of its product-destinations, one year before (February 27, 2009-February 26, 2010) and one year after the earthquake (February 27, 2010-February 26, 2011). Second, we have access to additional firm-level data from the annual manufacturing survey ENIA (*Encuesta Nacional Industrial Anual*) conducted by the INE. This survey covers all manufacturing establishments in the country with more than 10 employees.[13] Data therein allow us to explicitly assess whether there have been heterogeneous effects across groups of firms, control for input sourcing, and combined with additional information provided by the INE, account for damages to production facilities. Both datasets have been merged using the ENIA firm identifiers –NUIs- after recording of customs data by the INE.

The upper panel of Table 1 describes the Chilean manufacturing exporting firm in our sample in terms of their mean (median) export outcomes over the period February 27, 2009-February 26,

[11] The direct effects of some of the variables that form the interaction terms are already accounted for by the sets of fixed effects.

[12] Chile is divided into 15 regions (*regiones*), 54 provinces (*provincias*) and 346 municipalities (*comunas*). The *comuna* is the smallest administrative division of the country. In our dataset there are 332 origins (*comunas*) and 52 domestic destinations (customs), giving a total of 17,264 potential routes. A dozen of *comunas*, such as Isla de Pascua (Easter Island), are excluded because we do not have information on their road networks. The excluded *comunas*, however, are very small and do not register exports.

[13] These data correspond to 2007.

2010, i.e., the year before the earthquake.[14] On average, these firms sell abroad 7.2 products to 7.6 countries for 37.5 million US dollars. In so doing, firms use 3.1 customs. The average (median) distance between the plants and the customs through which their goods leave the country is 320 kilometers (130 kilometers).

The lower panels break these statistics according to the size of the companies. Thus, we distinguish between small and large companies. More precisely, we consider as small firms those whose number of employees is equal or smaller than the sample median and large firms those with those whose number of employees is above the sample median (105 employees). As expected, large firms export more, more products to more countries. It is also worth mentioning that the average distance to customs does not differ across these groups of firms.[15]

5. Econometric Results

In this section we implement the empirical approach outlined in Section 3 to estimate the impact of domestic road infrastructure on firms' exports at the product-destination level. We first present the baseline results and then go through several robustness checks including use of different thresholds delimiting affected exports, alternative specifications to account for potential remaining unobserved heterogeneity, removal of sectors that use to some extent other transportation modes in shipping their goods within Chile as well as firms and *comunas* more directly damaged by the earthquake and those heavily relying on intermediate inputs to rule out violations of the exclusion restriction, and placebo exercises to detect potential preexisting diverging trends in the outcome variable that might drive our results. Second, we investigate the channels through which observed effects on export values take place. More specifically, we examine whether and how diminished transport infrastructure influenced the quantity shipped, the number of shipments, and the average value and quantity per shipment. Finally, we explore whether there are heterogeneous effects across groups of firms (small vs. large) and products (undifferentiated vs. differentiated, light vs. heavy, and time insensitive vs. time sensitive).

[14] Our main sample includes all manufacturing firms with more than 10 employees that registered at least one export between February 27, 2009 and February 26, 2011. The total number of firms is 1,093.

[15] The largest sectors in terms of the number of firms are manufacture of food products and beverages, manufacture of chemicals and chemical products, and manufacture of rubber and plastic products, which jointly account for approximately 50% of the total. It is worth mentioning that the Kolmogorov-Sminorv test suggests that there are no significant differences in the distribution of the number of companies across sectors or provinces between the affected and non-affected groups. These test results are available from the authors upon request.

5.1 Baseline Results

Column (1) of Table 2 presents estimates of Equation (2). These estimates suggest that internal transport infrastructure has a significant effect on exports. In particular, the estimated coefficient on the variable of interest indicates that exports whose shipments had to be rerouted because their original routes became impassable have had a rate a growth 33.7% (($e^{-0.411}$-1)x100=-33.7) lower that their non-affected counterparts.[16] In assessing the significance of this effect, besides heteroscedasticity-consistent standard errors, we also consider standard errors clustered at the *comuna*, region, and sector level as well as their combinations. The result is robust to these alternative clustering.[17] Hereafter, inference will be based on standard errors clustered by region-2-digit sector. The reason is that, being geographically localized, the earthquake may have resulted in correlated exports stemming from the same region, particularly from producers belonging to given sectors, which in turn tend to be spatially concentrated.[18]

Given that the average (logarithmic) distance traveled to the exit point would have increased 23.7%, the baseline point estimate implies that the distance elasticity of exports would be -1.42. Moreover, a simple back-of-the-envelope calculation reveals that, in the absence of changes in domestic road infrastructure, total annual industrial exports would have been 6.3% larger over the period February 27, 2010-February 26, 2011.[19] Such an aggregate figure, which -as stated above- should basically be seen as the short run response of industrial exports to a disruption in transport infrastructure, is larger than that implied by the estimates of the multi-country gravity

[16] The effect estimated above can originate from both relative decreases in exports using damaged routes and relative increases in exports utilizing undamaged routes. Data inspection reveals that exports whose routes were affected by the earthquake are overrepresented among those that declined. In particular, according to a proportion test, the share of observations that these exports account for in the group with negative changes is significantly larger than that in the group with positive changes. In fact, estimates of modified version of Equation (2) where the dependent variable is a binary indicator taking the value of one if exports decreased between the pre- and post-earthquake periods and zero otherwise suggest that exports that were shipped along routes that became impassable are significantly more likely to have decreased between these two years. Further, these exports registered stronger reductions and weaker expansions that their counterparts that did not face diminished road infrastructure. More specifically, tests t of differences in means indicate that, among exports with negative changes, those whose routes were damaged had an average (logarithmic) decrease rate 9.4% larger (in absolute value) that those with undamaged roads and, among exports with positive changes, the former had an average (logarithmic) increase rate 12.1% smaller than the latter, when observations actually entering the estimation are considered. These differences are statistically different from zero in both cases. Similar conclusions are drawn when computing tests of difference in medians. These estimation results are available from the authors upon request.

[17] Further, it remains so when using less aggregated levels of clustering, including firm, product, country, firm-product, firm-country, and product-country. These estimates are available from the authors upon request.

[18] Standard errors clustered by region or *comuna* might have been alternatively used as reference. However, as mentioned above, Chile only has 15 regions. This is a small number of groups to be an appropriate benchmark clustering level (e.g., Wooldridge, 2003; 2006; and Hansen, 2007). While, in contrast, there is a relatively large number of *comunas*, exports are likely be correlated across them, because the earthquake affected larger areas and firms in given sectors tend to be located on both sides of their boundaries. Still, virtually all our main results are robust to using standard errors clustered by region and *comuna*. A set of tables reporting estimates along with these alternative standard errors is available from the authors upon request.

[19] In computing this figure, we assume that exports whose routes were damaged by the earthquake would have grown 33.7% more or would have declined 33.7% less, whereas exports whose routes remained undamaged have been taken as such.

equation reported in Gassebner et al. (2010) [20], and roughly corresponds to 4.5 times the amount invested by the Chilean government in rebuilding roads (see MOP; 2010b).

Firms can use different customs and accordingly different routes to ship a given product to a given country. This could be explained, for instance, by the location of the specific destination within the importing country. So far, we define as affected all firm-product-destination exports for which at least one of the least cost routes used to ship them was damaged by the earthquake. In the second and third column of Table 2, we present estimation results obtained when setting different thresholds, namely, when more than 50% of the routes originally used suffered from damages and when all routes experienced transit interruptions.[21] These results are qualitatively similar to our original ones.[22]

The frequency of our data also allows us to examine the timing of the effects. In particular, we have investigated whether these effects were different for the first and the last six months of the year following the earthquake. More specifically, we have estimated Equation (2) on common observations for both sub-periods allowing for the estimated coefficient on the binary variable capturing damages to road infrastructure to differ among them but imposing common firm and product-destination fixed effects. These estimated coefficients indicate the impacts were similar across semesters. [23]

In addition to the impact on the export intensive margin (i.e., continuing flows), diminished transport infrastructure and hence increased transport costs may have caused some exports to disappear. Hence, we have also explored the effect of the changes in available road infrastructure on the extensive margin. In so doing, we have used a binary indicator that takes the value of one if an export continues from the first to the second year and 0 otherwise as the dependent variable in Equation (2) and have estimated the resulting linear probability model on the sample consisting on all positive exports in the initial year.[24] Estimation results reveal that infrastructure did not appear to have significantly affected export probability.[25] *A priori*, this is not surprising.

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[20] According to their estimates, a major disaster would cause total exports of a small democratic country such as Costa Rica to decline by 3.9%. Export change would be predictably even smaller for a country with a larger area such as Chile.

[21] Nearly 84% of the 8,209 firm-product-destination observations with affected routes in our estimating sample correspond to cases in which all routes at this level were damaged.

[22] The differences in the point estimates across thresholds might be partially explained by differences in the alternative routes outside of the set initially used. In an alternative estimation, we have used the share of roads damaged by the earthquake, instead of the binary indicator, as our main explanatory variable. Results from this estimation indicate that, as expected, exports with a higher portion of their routes unusable were more strongly hit. These results are available from the authors upon request.

[23] These estimation results are available from the authors upon request.

[24] Since covariates are dummy variables for mutually exclusive and exhaustive categories, this model is completely general and there is therefore no need to resort to non-linear models (see, e.g., Wooldridge, 2002).

[25] These results are available from the authors upon request.

Infrastructure shortage is likely to have been seen as a temporary problem leading to a transitory increase in variable transport costs, so that firms may have preferred to keep exporting despite the less favorable conditions in order to avoid paying the fixed costs associated with reentry.

5.2 Robustness

Our estimation strategy combines first-differencing and a rich set of fixed effects to account for multiple potential confounding factors. Admittedly, this strategy imposes specific restrictions on the estimating sample. For example, by including firm fixed effects, we are identifying the effect of interest from within firm changes in exports for damaged relative to undamaged routes. This implies that firms with all or none of their product-destination routes affected by the earthquake do not actually contribute to this identification. Approximately 7,000 observations in our sample correspond to firms with both damaged and undamaged routes. Figure 3 shows the distribution of firms' share of product destination routes that became unusable for these observations. In addition, the cleanness of the approach might come at the expense of over-controlling for the equilibrium effects of the earthquake on output and prices. Hence, we have estimated a modified version of Equation (2) with *comuna* (*comuna*-4 digit sector) instead of firm fixed effects, where the former aims at controlling for common shocks and compensating policies for firms located in their respective territories (and belonging to given sectors). In this case, identification primarily comes from within *comuna* (*comuna*-sector) across firms changes in exports for affected and unaffected roads.[26] Estimation results are presented in the first two columns of Table 3.[27] Although smaller, estimates are highly significant, thus essentially confirming the baseline.

On the other hand, while we have included comprehensive sets of fixed effects that allow us to control for unobserved firm and product-destination shocks, there might potentially be space for remaining heterogeneity that contaminates our estimates. Thus, for instance, more affected firms may have received support from Chile's national export promotion organization – PROCHILE- to participate in trade missions and international marketing events leading to foreign sales, in which case we would be underestimating the effect of interest (see, e.g., Volpe

[26] We have also estimated an equation without firm and product-destination fixed effects and with just the latter for both the entire sample and just on those observations that actually enter the estimation. Again, the estimated coefficients are smaller, but remain highly significant. These results are available from the authors upon request.

[27] Roughly 83% and 52% of the observations correspond to *comunas* and *comuna*-sectors pairs with both damaged and non-damaged routes, respectively.

Martincus and Carballo, 2010). Similarly, there might have occurred shocks to input provision that might have differential effects on production across goods or changes in firms' competencies across them. We have therefore also estimated alternative specifications in which we include firm-country or firm-product fixed effects instead of merely firm fixed effects. Estimates are reported in columns 4 and 5 of Table 3. These estimates generally corroborate our initial findings.[28]

The previous estimations control for the influence of a broad range of unobserved factors, but unfortunately they cannot entirely rule out that the estimated effects also partially capture production shocks. This could have been particularly the case, for instance, for firms that experienced production disruptions that were asymmetric across these products and passed on the associated product-specific output changes in a non-proportional manner across destinations To deal with this concern we start by noticing there may be more than one exit port for each firm-product-destination combination, so that different routes can be used in shipping a good to a destination country. Hence, in principle, we can estimate a variant of Equation (2) that incorporates firm-product-destination fixed effects on data at the firm-product-customs-destination level, in which case identification would come from the within firm-product-destination variation in exports across routes. This of course requires a sufficiently large number of firm-product-destination triples for which at least one of their roads was damaged and at least another road remained undamaged. In our database, there are 22,479 observations that are present in both periods at this level, from which 1,259 correspond to triples featuring coexistence of affected and non-affected roads. In the last two column of Table 3, we report the results from such an alternative estimation on these highly disaggregated data, both excluding and including customs fixed effects. These results are remarkably in line with those based in the data at the firm-product-destination level.

Furthermore, there may be other modes of transport besides the truck (e.g., rail). In Chile the overall percentage share of these other modes in total foreign trade cargo shipped domestically does not exceed 6%. However, there are specific sectors for which these alternative modes

[28] Foreign buyers who were well informed about the earthquake and the exact location of their Chilean providers might have become doubtful about the ability of these firms to deliver goods on time and might have precautionary switched to alternative sources thus reducing their demand for the goods in question. In order to check whether this might create a problem to our estimates, we have estimated a modified version of the main estimating equation in which product-destination fixed effects are replaced with region-product-destination fixed effects to account for any regionally differential changes in foreign demand associated with import reductions decided by buyers based on the region in which their Chilean suppliers are located. Estimates from this equation do not significantly differ from those presented here and are available from the authors upon request.

account for a non-negligible portion of their goods' total cargos. This is particularly the case with manufacture of paper and paper products (ISIC3-2101), manufacture of basic precious and non-ferrous metals (ISIC3-2720), manufacture of coke oven and refined petroleum products (ISIC3-2310 and 2320), manufacture of basic chemicals (ISIC3-2411, 2412, and 2413) and manufacture of other chemical products (ISIC3-2421, 2422, 2423, 2424, and 2429) (see *Ministerio de Transporte y Telecomunicaciones* (MTT), 2009). Hence, we cumulatively exclude firms in these sectors and re-estimate Equation (2) on the resulting restricted samples. Estimates are shown in rows two to six of the first column in the upper panel of Table 4. These estimates are virtually identical to those presented before.[29]

Our empirical approach relies on three main identifying assumptions. First, the earthquake has affected exports only through the damages it caused to road infrastructure and the associated increase in transport costs. This restriction would be violated if this disaster would have also generated damages other than those on this infrastructure that have negatively affected exports. This would be for instance the case with destruction of production facilities, ports, airports, and electricity generating plants, among others.[30] If this other damages disproportionately affected exports with impassable routes we would be overestimating the true export effects of domestic transport infrastructure. In order to address this concern, we first exclude those firms whose production suffered from disruptions as a consequence of the damages caused by the earthquake in their plants using a list kindly provided by the INE. Second, we additionally remove from our sample all firms located in the *comunas* of Talcahuano (ID 8110), Concepción (ID 8101), and Coronel (ID 8102), which experienced longer blackouts than the national average (see ECLAC, 2010).[31] Further, while some ports and airports were affected, most of them were already fully operative only three to five days after the earthquake. There was only one port –Talcahuano-, which did not return to full operation even after nine months of the shock. Hence, we exclude observations involving this port from our sample. Finally, notice that damaged routes may have posed not only greater obstacles to export products, but also to source required inputs to produce

[29] The earthquake also damaged the railway system. Around 40% of the railways were somehow affected (see EFE, 2010). The damages of the quake were mostly concentrated in the Bio-Bio region, where the railway is primarily used for the transportation of cellulose, including paper and paper products. Hence, substitution between modes was virtually not an option for firms. Importantly, as shown in Table 4, our estimates are not sensitive to the inclusion or exclusion of companies in those industries that resort more intensively to railways.

[30] One might also think that the earthquake may have destroyed part of the truck fleets or that a portion of these fleets had to be used for purposes other than good transportation such as removal of rubbles, reconstruction, or shipments of consumption goods to affected areas. However, according to interviews we held with relevant logistic operators, truck fleets neither suffered substantial direct damages nor experienced any noticeable restriction on its load capacity.

[31] Even though the earthquake caused significant electrical interruptions, almost 90% of the service was already reestablished in less than a week (see ECLAC, 2010).

them. Thus, to the extent that this is not fully controlled for by the firm fixed effects (or the firm-product fixed effects as in Table 3), our estimates would be capturing the direct effect on export plus the impact on input sourcing. We therefore also restrict the estimating sample to those firms whose share of intermediate costs in total production value and whose number of inputs used are below the median.[32] Results from these alternative estimations are presented in the rows nine and ten of the first panel of Table 4. These results do not significantly differ from the baseline.

The second identifying assumption requires that, in absence of the earthquake, affected and non-affected exports would have followed parallel trends over time. The plausibility of this assumption can be assessed by performing a placebo test. In order to conduct this test, we artificially set February 27, 2009 as the date the earthquake took place instead of February 27, 2010 and accordingly compare affected and non-affected exports between February 27, 2008 and February 26, 2010, using Equation (2). We show these estimates in the second column of the upper panel of Table 4. Reassuringly, none of the estimated coefficients are statistically significant. In short, there is no indication of preexisting diverging trends in exports.

Third, the analysis assumes that rerouting of shipments whose original routes were damaged has not caused congestion in alternative, non affected routes, and has consequently not influenced exports initially transported along them. If this assumption would not hold, we would be underestimating the true impact of transport infrastructure on exports. In the lower panel of Table 4, we assess to what extent this is the case by comparing our baseline estimated effects with those obtained when the control group is restricted to export flows that did not experience increased (trade-related) traffic in all of their routes.[33] The test indicates that estimates do not significantly differ from each other, thus providing support to our strategy.

Hence, there is robust evidence suggesting that the damages to road infrastructure caused by earthquake and the associated increase in domestic transport costs have had a significant negative effect on exports.

[32] We have alternatively excluded those firms whose share of imported inputs in total production value and number of these inputs are above the median. Estimates do not differ from those presented here and are available from the authors upon request.

[33] These routes are identified using the procedure explained in Section 2 and the Appendix. The results are virtually the same when the exports that registered increased traffic in more than 50% of their routes are excluded from the control group.

5.3 *Channels and Heterogeneous Effects*

We next explore the channels through which this effect arises. In particular, we estimate the impact of road infrastructure on the quantity (weight) shipped, the unit values, the number of shipments, and the average value and quantity per shipment, based on Equation (2). Estimation results are presented in Table 5. These results reveal that diminished transport infrastructure has primarily affected the number of shipments and, to a lesser extent, the average quantity per shipment-, and thereby the quantity shipped. Noteworthy, unit values seem to have slightly increased as a consequence of the larger freight costs implied by the reduction road availability.[34] This is consistent with our expectations as these are f.o.b. values and are accordingly measured at the customs.[35]

Finally, we examine whether there are heterogeneous effects across firms and products. This is done in Tables 6 to 8. In Tables 6 and 7 we report estimates from alternative specifications of Equation (3), in which we allow for different impacts for small and large companies as defined above and additionally for differentiated and non-differentiated goods, respectively.[36] These estimates indicate that negative effects would appear to have been particularly strong for large firms exporting non-differentiated products.[37] More precisely, such exports that had to be shipped over longer distances have had a growth rate 40.1% ($e^{-0.513}$-1)x100=-40.1) lower than those whose distances remained unaltered.[38] The products that fall in this category are primarily

[34] Arguably, price movements might have led to developments along the extensive margin. As mentioned above, we do not find evidence supporting these effects. More precisely, firm-product-destination export flows whose original routes became blocked do not seem to have been more likely to disappear. In this regard, it is worth mentioning that we have also explored whether such a phenomenon occurred at a higher levels of aggregation. In particular, products whose prices raised the most as a consequence of the higher transport costs associated with diminished transport infrastructure may have dropped out of the trade bundle. A similar consideration also applies at the firm level. Thus, firms whose products experienced on average the largest increases may have not been able to place these products abroad and may accordingly have been forced to exit the export markets. In order to informally test to what extent this might be an issue, we regress a binary indicator capturing presence of the firm, product, or firm-product in our treatment variable redefined at the respective level, while controlling for unobserved regional and sectoral factors through a comprehensive set of municipal and sectoral fixed effects as appropriate. Estimation results suggest that this does not appear to have been the case. These estimation results are available from the authors upon request.

[35] Hummels and Skiba (2004) find that f.o.b. prices increase with international freight rates. More specifically, their estimation results suggest that doubling freight costs increase f.o.b. prices by 80-141 percent. These results provide empirical support to the Alchian-Allen conjecture.

[36] We use the classification developed by Rauch (1999). This classification distinguishes among homogeneous goods that are traded in organized exchanges, reference-priced goods that have reference prices quoted in specialized publications, and differentiated goods that are neither traded in organized exchanges nor have reference prices (i.e., prices do not convey all the relevant information for international trade on these goods). In this analysis, we pool together homogeneous and reference-priced goods and specifically follow the conservative classification. Results remain virtually the same when using instead the liberal version of the aforementioned classification and alternative firm size categorizations (e.g., segmentation based on the formal definition used by INE, according to which firms with up to 50 employees are small). These results are available from the authors upon request.

[37] We should mention herein that no significant differences in export growth rates are observed across size groups over the period February 27, 2008 and February 26, 2010. These placebo estimates are available from the authors upon request.

[38] One could imagine that diminished transport infrastructure may have affected differently small and large firm export margins. Thus, large firms may have mostly kept exporting and accordingly the impacts would be primarily observed on the intensive margin, whereas their smaller counterparts may have tended to directly stop exporting, so that the effects would mainly show up on the extensive margin. However, estimates

beverages; preparations of vegetables; preparations of meat; wood articles; and paper and paperboard. These products jointly account for almost 90% of the export flows involving non-differentiated goods exported by large manufacturing firms. We should mention herein that, even though smaller firms selling abroad these goods also appeared to have been somehow affected, effects on these companies are not robust as they become insignificant as soon as alternative standard errors (e.g., clustered by *comuna*) or specifications (e.g., equation with *comuna* fixed effects instead of firm fixed effects) are used.[39]

The reduction in the value of exports of undifferentiated products associated with diminished transport infrastructure comes from a decline in the number of shipments and consequently in the quantity shipped. Notice that, on the other hand, firms increased their prices of these products. The rationale for these findings is fivefold.

First, non-differentiated manufacturing products are predictably heavier than their differentiated counterparts. Indeed, in our sample, the former goods have larger mean and median weight-to-value ratios than the latter goods, and these differences are statistically significant. Detours and longer distances may accordingly have raised transport costs relatively more for non-differentiated products and caused a stronger negative impact on their exports. In order to examine whether this has been actually the case, we re-estimate Equation (3) allowing for asymmetric effects between light and heavy goods (i.e., goods whose pre-earthquake weight-to-value ratios were below or at and above the product-level sample median, respectively).[40] Estimates are reported in the upper panel of Table 8. These estimates suggest that exports of heavy products seem to have suffered significantly more from the shock to domestic road infrastructure. More precisely, negative effects are almost exclusively significant for these exports.

Second, undifferentiated manufacturing products may be more time-sensitive.[41] Time sensitivity can be proxied by the frequency at which goods are shipped abroad. Consistently, in our data the mean and the median of the frequency of shipments are significantly larger for more homogeneous products. We accordingly investigate the existence of possible heterogeneous export responses along this dimension by re-estimating Equation (3), this time permitting

of a linear probability model version of Equation (3) indicate that this is not the case. More specifically, transport costs did not seem to have influenced export probability of neither group of firms. These results are available from the authors upon request.

[39] These estimation results are available from the authors upon request.

[40] Due to the presence of outliers, all summary statistics used to create product categories have been computed after removal the top one percent of the respective distribution of the product-level measure.

[41] Alternatively, holding inventories for these products may be more costly.

different effects for time-insensitive and time-sensitive goods (i.e., goods whose pre-earthquake frequency of shipments were below or at and above the sample product-level median, respectively). Estimation results, which are shown in the bottom panel of Table 8, clearly indicate that, as expected, time-sensitive products experienced larger foreign sales loses as a consequence of the negative read infrastructure shock.

Third, from the firm point of view, large companies are likely to be more capital intensive and may accordingly face higher average transport costs.[42] This is particularly the case with firms that belong to basic sectors –as many large Chilean companies do-, which tend to produce relatively heavy bulk items (see Forslid and Okubo, 2011). Hence, exports of these firms could be expected to be more severely affected. In fact, this is what we observe when we re-estimate Equation (3) allowing for the effects of diminished transport infrastructure to vary across groups of firms with different capital intensity. More specifically, these effects are only significant for companies with relatively high capital-labor ratios.[43]

Fourth, as mentioned above, the earthquake caused damages to several roads, which constrained the speed at which trucks could travel along, and even made some of them completely impassable, thus forcing to reroute and accordingly to ship goods over longer distances to reach the exit points. The increase on the distance traveled –and thereby in the time required to complete each shipment and the cost incurred- was on average larger for large firms. The reason is that the larger trucks that transported their larger average shipments could neither use lower quality routes nor several routes (or bridges) with structural damages as they were subject to load constraints (see, e.g., MOP, 2010c and MOP, 2010d).[44] As a consequence, these vehicles had to take longer detours. Further, according to data gathered from logistic operators, there was a partial switching towards smaller trucks, which could explain the negative effect on average shipment size in terms of quantity detected for large firms.

Fifth, large firms are present in many markets, in some of which only a few of their peers are also active –the so-called “less popular” destinations-. These firms tend therefore to be more regularly affected by changes in trade costs (and demand) across a range of markets and can

[42] Firm scale can also affect transport costs in the opposite direction, making freight rates lower for large firms. Indeed, among other factors, these costs may be influenced by both firm scale and capital intensity as proxies for the characteristics of the average good produced by the firm (see Forslid and Okubo, 2011).
[43] These estimation results are available from the authors upon request.
[44] The average shipment size of larger firms is 40% larger than that of their small counterparts.

accordingly be expected to have more dynamic trade patterns (see, e.g., Lawless, 2009).[45] This is particularly the case with companies exporting non-differentiated goods. Given the relatively high elasticity of the demand for these goods, higher domestic transport costs and thereby total trade costs can predictably translate more directly into a reduction of their exports in a number of markets.[46]

Of course, alternative explanations can be thought of for these findings. Thus, for instance, the different effects of diminished transport infrastructure on large and small exporters might be driven by the higher likelihood of the former to actually remain in the sample after first-differencing. Nevertheless, this does not appear to hold in our data. Estimates of a modified version of Equation (3) whereby firm fixed effects are replaced with *comuna* fixed effects confirm our finding. Alternatively, such a finding might be partially explained by the fact that small exporters typically tend to trade with a few popular, most frequently neighboring destination markets, and routes to these destinations have been on average less affected because they extend away from the epicenter of the earthquake. This is particularly the case with Argentina. However, estimation results do not substantially change when we focus on the incidence of transport infrastructure disruptions on trade with countries other than Argentina. Furthermore, several homogeneous products are seasonal and even perishable.[47] It might thus be possible that observed effects on their exports reflects not only reduced transport infrastructure, but also firm-product specific production shocks that are propagated asymmetrically across destinations. However, results remain exactly the same when we estimate a modified version of Equation (3) with firm-product-destination fixed effects on firm-product-custom-destination level data.

Moreover, the virtual absence of significant impacts on large firms' exports of differentiated products over a one-year period might the consequence of that the roads used by these companies are among the most important in the country and were accordingly repaired first. The plausibility of this competing explanation can be assessed by comparing the effects of diminished road infrastructure on different firm groups' exports for the first and second semester after the earthquake. The patterns of these results do not seem to differ from those observed for

[45] Lawless (2009) observes that firms that are present in many markets exhibit more dynamic export participation statuses. Our findings can then be seen as complementary to hers in the sense that we find that their export levels are also more sensitive to changes in trade costs. In other words, large firms and small firms face demand curves with different average elasticities.

[46] Alternatively, such companies are likely to have smaller markups and thus to be in a less favorable position to absorb these increased trade costs.

[47] The earthquake hit Chile at the end of February, which is precisely the harvest time for timber, grapes, and other fruits and vegetables.

the entire year. In a complementary exercise, we remove from the sub-sample of exports whose routes suffered from damages those for which these routes had been rebuilt by August 2010 using information kindly provided by the MOP, and re-estimate Equation (3). As long as there is enough number of observations in each group -as in our data-, we should then be able to detect the effect in question if it was actually present. Still, again, estimates coincide with those shown here.

Finally, it might be argued that general equilibrium effects played a role in shaping observed differential impacts. More precisely, foreign buyers of undifferentiated products may have more easily replaced Chilean suppliers with affected routes with their peers not facing these infrastructure constraints. If this were true we should see that exports of homogeneous products from firms with no damaged routes have grown more if these products were also exported to the same destination by firms whose routes were affected by the earthquake.[48] To check this possibility, we carry out regressions of export growth at the firm-product-destination level on a binary indicator taking the value of one if the product is also exported to the same country by at least one firm facing reduced road infrastructure and zero otherwise –without and with firm fixed effects- on the sample of homogeneous products. Evidence based on these regressions suggests that this does not appear to have been the case.[49]

Summing up, our estimation results would indicate that the contraction in available road infrastructure seems to have particularly affected exports of more homogeneous goods from large companies.

6. Concluding Remarks

Very few studies have attempted to rigorously measure the effects of domestic transport infrastructure on trade flows. Our study fills this gap in the empirical literature. In particular, we estimate these effects and, in so doing, we address the potential endogeneity problem between domestic transport infrastructure and international trade by exploiting the random variation in this infrastructure arising from the earthquake that took place in Chile on February 27, 2010. By using a difference in difference estimator we compare the before and after change in affected

[48] A series of tables presenting all these estimation results are available from the authors upon request.
[49] Thus, instead of substituting among Chilean providers, importers seem to have substituted away from them.

exports with that of non-affected exports. Estimates reveal a significant negative effect on exports subject to the shock to domestic infrastructure, which primarily originates from a reduction in the number of shipments and hence of the quantity shipped. These effects appear to have been particularly strong for exports of non-differentiated goods from large companies. These results highlight the fact that infrastructure shortages can put a cap on the extent of firms' operations in foreign markets.

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Table 1

Descriptive Statistics		
All Firms		
Variable\Statistic	**Mean**	**Median**
Exports	37,500.00	605.60
Number of Products	7.24	4.00
Number of Countries	7.63	3.00
Number of Countries per Product	2.90	1.00
Number of Products per Country	3.10	2.00
Average Exports per Product	8,814.45	159.52
Average Exports per Country	2,887.65	175.02
Average Exports per Country and Product	1,811.98	69.83
Number of Customs	3.10	3.00
Number of Customs per Firm-Product-Country	1.30	1.00
Average Distance to Customs	0.32	0.13
Large Firms (Number of Employees>105)		
Variable\Statistic	**Mean**	**Median**
Exports	72,900.00	2,904.22
Number of Products	10.04	6.00
Number of Countries	10.50	6.00
Number of Countries per Product	2.90	1.00
Number of Products per Country	3.20	2.00
Average Exports per Product	17,100.00	390.64
Average Exports per Country	5,292.58	429.59
Average Exports per Country and Product	3,362.61	146.57
Number of Customs	3.80	4.00
Number of Customs per Firm-Product-Country	1.30	1.00
Average Distance to Customs	0.32	0.13
Small Firms (Number of Employees<=105)		
Variable\Statistic	**Mean**	**Median**
Exports	2,207.13	152.78
Number of Products	4.47	2.00
Number of Countries	4.78	2.00
Number of Countries per Product	2.90	1.00
Number of Products per Country	2.90	2.00
Average Exports per Product	468.05	58.34
Average Exports per Country	459.19	67.11
Average Exports per Country and Product	246.18	30.87
Number of Customs	2.40	2.00
Number of Customs per Firm-Product-Country	1.20	1.00
Average Distance to Customs	0.32	0.13

Source: Authors' calculations based on data from *Servicio Nacional de Aduanas* and INE.

The complete sample includes all manufacturing firms that registered at least one export between February 27, 2009 and February 26, 2011. The total number of firms is 1,093. Exports and average exports are expressed in thousands of US dollars. Average distance to customs is expressed in thousands of kilometers.

Table 2

Impact of Diminished Domestic Road Infrastructure on Firms' Exports Sample: Manufacturing Firms, 2009-2010			
	D>0	**D>50**	**D=100**
D	-0.411	-0.474	-0.417
Heteroscedasticity-Consistent	(0.071)***	(0.131)***	(0.143)***
Cluster-Region	(0.138)***	(0.221)**	(0.227)*
Cluster-*Comuna*	(0.147)***	(0.198)**	(0.201)**
Cluster-Sector ISIC 2 Digit	(0.089)***	(0.081)***	(0.088)***
Cluster-Sector ISIC 4 Digit	(0.097)***	(0.208)**	(0.185)**
Cluster-Region-Sector ISIC 2 Digit	(0.115)***	(0.198)**	(0.202)**
Cluster-Region-Sector ISIC 4 Digit	(0.122)***	(0.199)**	(0.202)**
Cluster-*Comuna*-Sector ISIC 2 Digit	(0.147)***	(0.195)**	(0.197)**
Cluster-*Comuna*-Sector ISIC 4 Digit	(0.147)***	(0.193)**	(0.195)**
Firm Fixed Effect	Yes	Yes	Yes
Product-Destination Fixed Effect	Yes	Yes	Yes
Observations	20,171	19,042	18,823

Source: Authors' calculations based on data from S*ervicio Nacional de Aduanas*.
The table reports estimates of Equation (2) using alternative thresholds to determine which exports have been subject to the domestic transportation shock. The dependent variable is the change in the natural logarithm of export value at the firm-product-country level. D>0 corresponds to exports with at least one of their routes damaged by the earthquake; D>50 corresponds to exports with more than 50% of their routes damaged by the earthquake; and D=100 corresponds to exports that suffered damages in all of their routes. Firm fixed effects and product-destination fixed effects are included (but not reported).Robust standard errors reported in parentheses below the estimated coefficient. Standard errors clustered at alternative levels are shown next. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The significance indicator is along with the respective standard errors. The number of firms included in the estimation sample is 850.

Table 3

Impact of Diminished Domestic Road Infrastructure on Firms' Exports Sample: Manufacturing Firms, 2009-2010, February 27, 2009-Februrary 26, 2011							
	Data Aggregation Level						
	Firm-Product-Destination					Firm-Product-Customs-Destination	
D	-0.205*** (0.041)	-0.215*** (0.042)	-0.411*** (0.115)	-0.327** (0.133)	-0.538*** (0.144)	-0.535*** (0.150)	-0.505*** (0.102)
Comuna Fixed Effect	Yes	No	No	No	No	No	No
Comuna -ISIC 4 Digit Fixed Effect	No	Yes	No	No	No	No	No
Firm Fixed Effect	No	No	Yes	No	No	No	No
Firm-Product Fixed Effect	No	No	No	Yes	No	No	No
Firm-Destination Fixed Effect	No	No	No	No	Yes	No	No
Product-Destination Fixed Effect	Yes	No	Yes	Yes	Yes	No	No
Firm-Product-Destination Fixed Effect	No	No	No	No	No	Yes	Yes
Customs Fixed Effect	No	No	No	No	No	No	Yes

Source: Authors' calculations based on data from S*ervicio Nacional de Aduanas*.

The table reports estimates of alternative specifications of Equation (2) as well as for different data aggregation levels. In the first five columns, the dependent variable is the change in the natural logarithm of export value at the firm-product-country level, whereas in the last two columns the dependent variable is the change in the natural logarithm of export value at the firm-product-customs-country level. *Comuna* fixed effects and product-country fixed effects are included in the first column; comuna-4-digit ISIC sector fixed effects and product-destination fixed effects are included in the second column; firm fixed effects and product-destination fixed effects are included in the third column; firm-product fixed effects and product-destination fixed effects are included in the fourth column; and firm-destination fixed effects and product-destination fixed effects are included in the fifth column; firm-product-destination fixed effects are included in the sixth column; and firm-product-destination fixed effects and customs fixed effects are included in the sixth column (but not reported). Standard errors clustered by region-2-digit ISIC sector are reported in parentheses below the estimated coefficients. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The number of observations is 20,171 for those estimations whose results are presented in the first five columns and 22,479 for those estimations whose results are presented in the last two columns.

Table 4

Impact of Diminished Domestic Road Infrastructure on Firms' Exports Exclusion Restriction, Placebo Test, and Congestion Sample: Manufacturing Firms		
Panel 1: Exclusion Restriction and Placebo Test		
Exclusions	**02/27/2009-02/26/2011**	**02/27/2008-02/26/2010**
None	-0.411***	0.109
	(0.115)	(0.163)
Sector 2101	-0.418***	0.103
	(0.118)	(0.163)
Sectors 2101 and 2720	-0.428***	0.105
	(0.123)	(0.166)
Sectors 2101, 2720, 2310, and 2320	-0.428***	0.105
	(0.123)	(0.166)
Sectors 2101, 2720, 2310, 2320, 2411, 2412, and 2413	-0.427***	0.104
	(0.121)	(0.164)
Sectors 2101, 2720, 2310, 2320, 2411, 2412, 2413, 2421, 2422, 2423, 2424, and 2429	-0.415***	0.100
	(0.114)	(0.162)
Sectors Above and Affected Firms	-0.415***	0.095
	(0.116)	(0.161)
Sectors Above, Affected Firms, and *Comunas* 8101, 8102, and 8110	-0.427***	0.074
	(0.128)	(0.170)
Sectors Above, Affected Firms, *Comunas* 8101, 8102, and 8110, and Firms with Share of Inputs above the Median	-0.327***	0.023
	(0.059)	(0.179)
Sectors Above, Affected Firms, *Comunas* 8101, 8102, and 8110, and Firms with Share and Number Inputs above the Median	-0.306**	0.017
	(0.069)	(0.148)
Panel 2: Congestion		
	All Observations	**No Congestion**
D	-0.411***	-0.457 ***
	(0.115)	(0.122)
Test of Equality of Estimated Coefficients		
$\chi^2(1)$	2.000	
[p-value]	[0.157]	
Firm Fixed Effect	Yes	Yes
Product-Destination Fixed Effect	Yes	Yes

Source: Authors' calculations based on data from S*ervicio Nacional de Aduanas* and INE.

The upper panel of the table reports estimates of Equation (2) on alternative samples. The dependent variable is the change in the natural logarithm of export value at the firm-product-country level. In rows two to six firms in the following sectors are cumulatively removed from the original sample: manufacture of paper and paper products (2101), manufacture of basic precious and non-ferrous metals (2720), manufacture of coke oven and refined petroleum products (2310 and 2320), manufacture of basic chemicals (2411, 2412, and 2413) and manufacture of other chemical products (2421, 2422, 2423, 2424, and 2429). In the seventh row we exclude those firms that experienced substantial production losses according to information provided by the INE. Next, we additionally remove all firms located in the *comunas* of Talcahuano (8110), Concepción (8101), and Coronel (8102).Finally, we leave aside all firms whose share of intermediate inputs in total production value and number of inputs used are above the median. In the first column the sample period is February 27, 2009-February 26, 2011, whereas in the second one is February 27, 2008-February 26, 2010 (placebo test). The lower panel presents the estimates of Equation (2) when the control group consists of all exports whose initial routes were not damaged by the earthquake and when this groups is restricted to those exports that did not experience increased (trade-related) traffic in all of their routes after this natural disaster occurred along with the statistics and the p-value of the test of equality of these estimates. Firm fixed effects and product-destination fixed effects are included (but not reported). Standard errors clustered by region-2-digit ISIC sector are reported between parentheses below the estimated coefficients. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The number of observations ranges between 4,646 and 20,171.

Table 5

Impact of Diminished Domestic Road Infrastructure on Firms' Exports Channels Sample: Manufacturing Firms, February 27, 2009-Februrary 26, 2011	
Exports	-0.411***
	(0.115)
Quantity	-0.471***
	(0.128)
Unit Value	0.060***
	(0.021)
Number of Shipments	-0.369***
	(0.119)
Average Exports per Shipment	-0.041*
	(0.024)
Average Quantity per Shipment	-0.100***
	(0.023)
Firm Fixed Effect	Yes
Product-Destination Fixed Effect	Yes
Observations	20,171

Source: Authors' calculations based on data from S*ervicio Nacional de Aduanas*.
The table reports estimates of Equation (2). The dependent variables are the change in the natural logarithm of export value, quantity (weight) shipped, unit value, number of shipments, average exports per shipment, and average quantity per shipment at the firm-product-country level. Firm fixed effects and product-destination fixed effects included (but not reported). Standard errors clustered by region-2-digit ISIC sector are reported in parentheses below the estimated coefficients. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

Table 6

Impact of Diminished Domestic Road Infrastructure on Firms' Exports by Size Categories Sample: Manufacturing Firms, February 27, 2009-Februrary 26, 2011			
	Small Firms	**Large Firms**	**Difference**
Exports	-0.160	-0.475***	0.315
	(0.171)	(0.146)	(0.260]
Quantity	-0.268*	-0.524***	0.256
	(0.153)	(0.162)	(0.252
Unit Value	0.109**	0.047**	0.061
	(0.051)	(0.024)	(0.059)
Number of Shipments	-0.200**	-0.413***	0.213*
	(0.089)	(0.130)	(0.110)
Average Exports per Shipment	0.040	-0.062**	0.102
	(0.160)	(0.030)	(0.180)
Average Quantity per Shipment	-0.067	-0.109***	0.042
	(0.145)	(0.037)	(0.172)
Firm Fixed Effect		Yes	
Product-Destination Fixed Effect		Yes	
Observations		20,171	

Source: Authors' calculations based on data from S*ervicio Nacional de Aduanas* and INE.
The table reports estimates of a specification of Equation (3) which allows for different effects for small firms (1-105 employees) and large firms (more than 105 employees). The dependent variables are the change in the natural logarithm of export value, quantity (weight) shipped, unit value, number of shipments, average exports per shipment, and average quantity per shipment at the firm-product-country level. Firm fixed effects and product-destination fixed effects included (but not reported). Standard errors clustered by region-2-digit ISIC sector are reported in parentheses below the estimated coefficients. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The number of firms included in the estimation sample is 850, from which 402 are small firms and 448 are large firms.

Table 7

Impact of Diminished Domestic Road Infrastructure on Firms' Exports by Size Categories and Product Types
Sample: Manufacturing Firms, February 27, 2009-Februrary 26, 2011

	Small Firms	Large Firms	Difference
Differentiated Products			
Exports	0.560	-0.282	0.842
	(0.538)	(0.171)	(0.525)
Quantity	0.135	-0.298*	0.433
	(0.542)	(0.173)	(0.524)
Unit Value	0.425	0.006	0.419
	(0.369)	(0.035)	(0.372)
Number of Shipments	0.001	-0.249*	0.250
	(0.264)	(0.130)	(0.279)
Average Exports per Shipment	0.558	-0.034	0.592
	(0.444)	(0.098)	(0.473)
Average Quantity per Shipment	0.139	-0.048	0.187
	(0.512)	(0.094)	(0.524)
Non-Differentiated Products			
	Small Firms	**Large Firms**	**Difference**
Exports	-0.205	-0.513***	0.308
	(0.131)	(0.183)	(0.265)
Quantity	-0.291**	-0.570***	0.278
	(0.141)	(0.200)	(0.289)
Unit Value	0.087***	0.057**	0.030
	(0.028)	(0.024)	(0.041)
Number of Shipments	-0.214**	-0.448***	0.234*
	(0.095)	(0.154)	(0.126)
Average Exports per Shipment	0.009	-0.065	0.074
	(0.140)	(0.041)	(0.173)
Average Quantity per Shipment	-0.077	-0.119**	0.042
	(0.151)	(0.052)	(0.197)
Firm Fixed Effect		Yes	
Product-Destination Fixed Effect		Yes	
Observations		20,171	

Source: Authors' calculations based on data from S*ervicio Nacional de Aduanas* and INE.

The table reports estimates of a specification of Equation (3) which allows for different effects for small firms (1-105 employees) and large firms (more than 105 employees) trading differentiated and non-differentiated (homogeneous and reference-priced) products as classified by Rauch (1999). The dependent variables are change in the natural logarithm of export value, quantity (weight) shipped, unit value, number of shipments, average exports per shipment, and average quantity per shipment at the firm-product-country level. All relevant interacting terms and their combination included. Firm fixed effects and product-destination fixed effects included (but not reported). Standard errors clustered by region-2-digit ISIC sector are reported in parentheses below the estimated coefficients. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. The number of firms included in the estimation sample is 850, from which 402 are small firms and 448 are large firms.

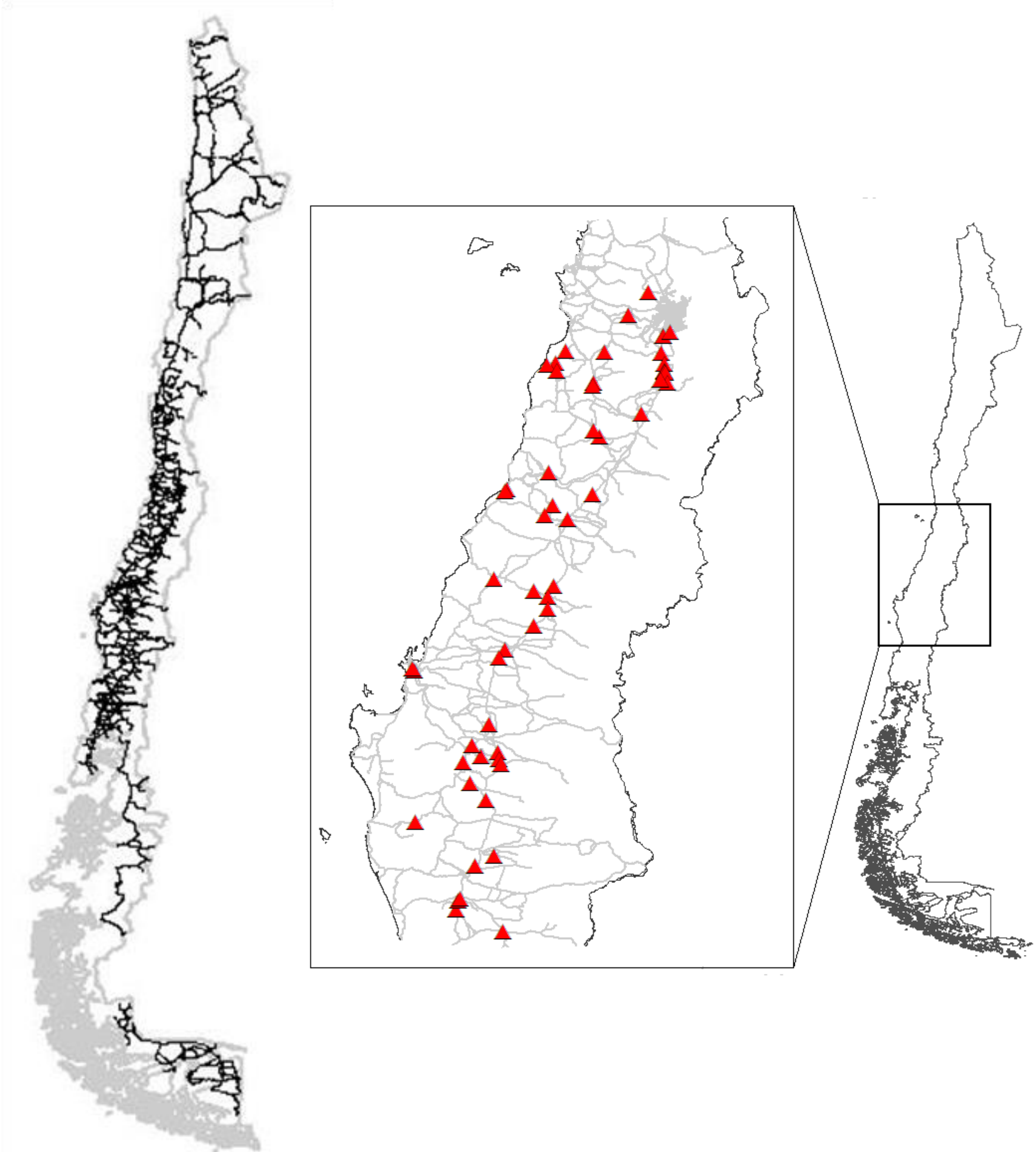
Table 8

Impact of Diminished Domestic Road Infrastructure on Firms' Exports by Product Types Sample: Manufacturing Firms, February 27, 2009-Februrary 26, 2011			
Light Products vs. Heavy Products			
	Light	**Heavy**	**Difference**
Exports	-0.507	-0.403***	0.104
	(0.318)	(0.123)	(0.354)
Quantity	-0.520*	-0.468***	0.051
	(0.302)	(0.137)	(0.340)
Unit Value	0.025	0.063***	0.038
	(0.075)	(0.020)	(0.071)
Number of Shipments	-0.320	-0.374***	-0.055
	(0.256)	(0.128)	(0.285)
Average Exports per Shipment	-0.187	-0.029	0.158
	(0.145)	(0.029)	(0.146)
Average Quantity per Shipment	-0.190	-0.093***	0.097
	(0.147)	(0.026)	(0.149)
Time-Insensitive Products and Time-Sensitive Products			
	Time-Insensitive	**Time-Sensitive**	**Difference**
Exports	-0.342***	-0.441***	-0.099***
	(0.123)	(0.117)	(0.037)
Quantity	-0.424***	-0.495***	-0.070*
	(0.134)	(0.131)	(0.039)
Unit Value	0.081***	0.053**	-0.029***
	(0.020)	(0.022)	(0.010)
Number of Shipments	-0.304**	-0.401***	-0.097***
	(0.129)	(0.120)	(0.029)
Average Exports per Shipment	-0.038	-0.041*	-0.002
	(0.039)	(0.023)	(0.031)
Average Quantity per Shipment	-0.119***	-0.092***	0.027
	(0.040)	(0.022)	(0.036)
Firm Fixed Effect		Yes	
Product-Destination Fixed Effect		Yes	
Observations		20,171	

Source: Authors' calculations based on data from S*ervicio Nacional de Aduanas* and INE.

The table reports estimates of a specification of Equation (3) which allows for different effects for light products (i.e., products whose pre-earthquake weight-to-value ratios were below or at the product-level sample median,) and heavy firms (i.e., products whose pre-earthquake weight-to-value ratios were above the product-level sample median) and for time-insensitive products (i.e., products whose pre-earthquake frequency of shipments were below or at the sample product-level median) and time-sensitive products (i.e., products whose pre-earthquake frequency of shipments were above the sample product-level median). The dependent variables are change in the natural logarithm of export value, quantity (weight) shipped, unit value, number of shipments, average exports per shipment, and average quantity per shipment at the firm-product-country level. All relevant interacting terms and their combination included. Firm fixed effects and product-destination fixed effects included (but not reported). Standard errors clustered by region-2-digit ISIC sector are reported in parentheses below the estimated coefficients. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

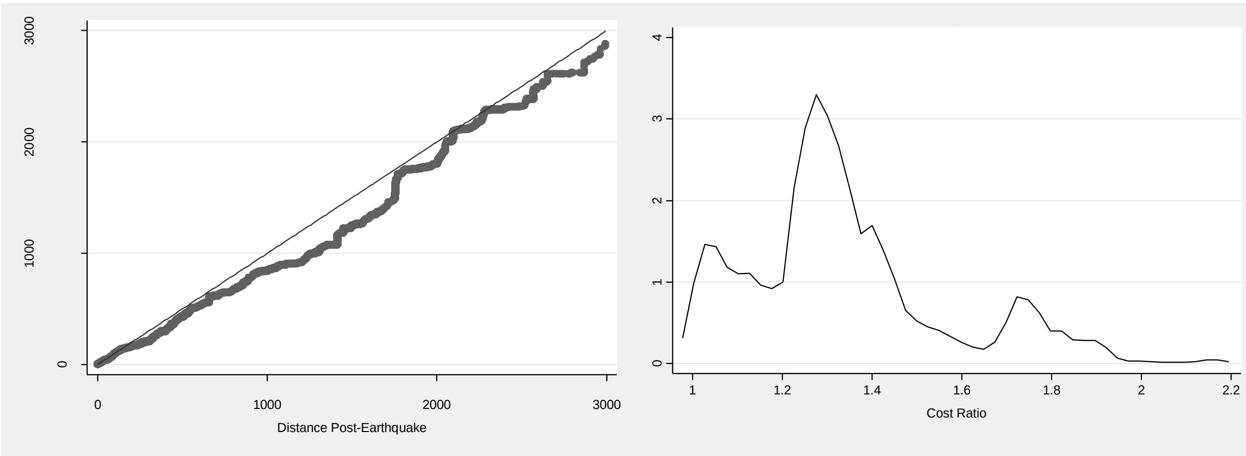
Figure 1
Chile's Road Network



ased on a GIS map from LDC and geo-referenced data from MOP.
ıry and secondary road network and the 55 points with complete traffic interruption
(red triangles).

Figure 2

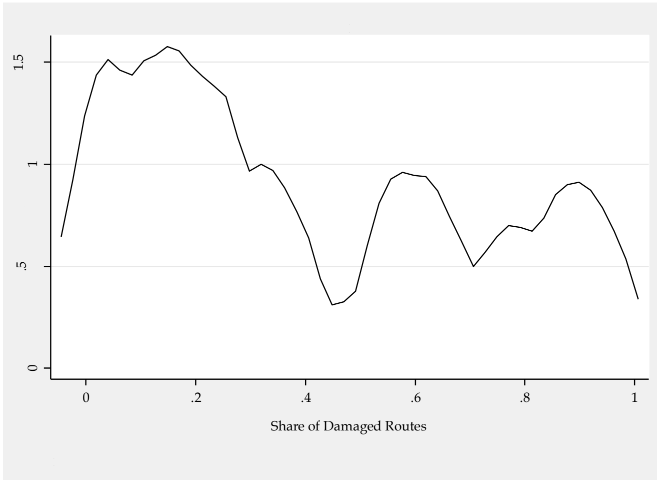
Distribution of Distances Traveled to the Exit Points and Transport Costs Before and After the Earthquake



The figure on the left is a quantile-quantile graph that plots the quantiles of the distances traveled (in kilometers) from the plant to the exiting customs before the earthquake (y-axis) against those traveled after the earthquake (x-axis) for exports that are positive in both periods, whereas the figure on the right is a kernel density estimate of the ratio of the transport costs after the earthquake to the transport costs before the earthquake for exports experiencing diminished domestic road infrastructure as a consequence of this natural disaster as computed according to the procedure outlined in the Appendix.

Figure 3

Distribution of the Share of Firms' Product-Destination Routes Damaged by the Earthquake



from MOP.
The figure is a kernel density estimate of the firms' share of product-destinations exports whose routes were damaged by the earthquake to their total number of product-destinations for firms with some of their routes affected (i.e., nor those without any route affected neither those with all their routes affected).

Appendix
Estimation of the Least-Cost Routes

The transport network of a country consists of a number of arcs of different types (e.g. highways, primary roads, secondary roads, etc). Along any particular arc, there are two types of costs: costs associated with distance and costs associated with time. The distance-related costs per kilometer are essentially fuel costs, tire renewing expenses, and maintenance operating costs. The time-related costs per hour are the labor costs, the insurance expenses, the depreciation costs, as well as carrier vehicle taxes and parking costs.

Let d_a denote the distance between the end-nodes of an arc *a*. The total distance-related costs incurred in connecting two locations *r* and *p* using route γ_{rp} is given by:

$$Dist\_C_{rp} = \sum_{a \in \gamma_{rp}} (fuel + tires + maintaince) d_a \quad \text{(A1)}$$

Let $s_a$be the speed along the arc a. Thus, the time for joining the arc nodes is $t_a = d_a / s_a$ and the total time-related costs incurred when connecting two locations *r* and *p* using the route γ_{rp} is given by:

$$Time\_C_{rp} = \sum_{a \in \gamma_{rp}} (wage + insure + depreciation + permits) \left(\sum_{a \in Z_{rp}} d_a / s_a \right) \quad \text{(A2)}$$

While there may be several different routes joining locations *r* and *p*, we are interested in the route with the lowest total costs. Hence, if Γ_{rp}denotes the set of all possible routes that join locations *r* and *p*, the optimization problem for finding the route with the minimum transport costs can be expressed as follows:

$$Total\_C_{rp} = \min_{\gamma_{rp} \in \Gamma_{rp}} \left(Dist\_C_{rp} + Time\_C_{rp} \right) \quad \text{(A3)}$$

This optimization problem is solved using geographic information system (GIS) software (ArcView) and a digitalized transport network of Chile that includes all the primary and secondary roads of the country. The network is populated using real distance and time-related costs data taken from an annual survey on the operational transport costs of land cargo services, *Encuesta de Servicio de Transporte de Carga por Carretera,* conducted by the INE. The survey covers trucking firms of all sizes and includes information for each firm on the numbers of trucks, capacity, tons carried, distance covered, as well as all the operational costs incurred during the year. Table A1 shows the average operation costs for all the firms, divided by distance-related costs, time-related costs and total costs.

Table A1

Operational Costs, 2008	
(1) Distance-related costs	
Pesos per Km per Ton	
Fuel	20.3
Lubricants	1.5
Maintance	5.4
Tire	2.2
Batteries	0.2
Other	2.4
Total	32.1
(2) Time-related costs	
Pesos per Hour per Ton	
Wages	733.4
Insurance	85.2
Depreciation	289.5
Permits	24.0
Total	1,132.2
(3) Total costs	
Pesos per Km per Ton	
Total	60.40

Source: Authors' calculation based on data from INE.
The table provides a weighted average of transport costs of operating trucks from 1.7 to 30 tons in Chile. The figures are calculated using the survey "Servicio de Transporte de Carga por Carretera" carried out by the INE. Total costs = (distance-related costs) + (time-related costs/average speed).