TOO FAR TO EXPORT

Domestic Transport Costs and Regional Export Disparities in Latin America and the Caribbean

Coordinated by Mauricio Mesquita Moreira
With Juan Blyde, Christian Volpe, and Danielken Molina

Special Report on Integration and Trade

IDB
Inter-American Development Bank

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>> Prologue

From the start, the IDB's trade and integration research agenda has focused on helping countries in Latin America and the Caribbean (LAC) develop policies and institutions for multipolar trade strategies based on unilateral, preferential, and multilateral liberalizations.

The agenda's early priorities reflected the legacy of the import substitution years, which left the region with high tariffs as well as a deep mistrust in the potential of trade and integration to promote growth. Against this background, we directed our resources mainly to providing theoretical and empirical support for the fledgling unilateral and preferential initiatives that were taking root around the region.

As open regionalism gained momentum, leading to the proverbial "spaghetti bowl," we shifted much of our efforts to explaining its costs—particularly those arising from mechanisms such as rules of origin—and to proposing solutions to minimize them, including enlarging and harmonizing the existing agreements; this was the subject of our 2009 flagship report *Bridging Regional Trade Agreements in the Americas*.

The demands brought by the proximity of the Doha Round completed this cycle, in which most of our attention was devoted to the so-called traditional trade costs. Then, as negotiations for the Round unfolded, we became increasingly aware that the region's trade agenda had to expand beyond the traditional issues to include "the other" trade costs—transport and logistics, information barriers, and customs procedures.

At least three good reasons justify this shift in emphasis. First, unilateral and preferential liberalizations had reduced tariffs to a fraction of what they were in the early 1990s. Second, the emergence of

Asia—whose seismic impact on LAC was the subject of a number our recent research reports (see *The Emergence of China*, 2006; *India: Latin America's Next Big Thing*, 2010 and *Shaping the Future*, 2012)—has pushed the region towards a specialization in transport-intensive goods, both commodities and time-sensitive manufacturing goods. And, third, the increasing fragmentation of world production and the development of international value chains (the subject of our next flagship report) have placed a premium on timelier and less expensive ways of shipping parts and components abroad.

This perception led to our first research foray on these issues, *Unclogging the Arteries* (2008), which showed that international freight costs are far and away the most important obstacle to trade, and that effective policies to address these costs are likely to offer the best returns in terms of both volume and diversification of trade.

This was followed by *Odyssey in International Markets* (2010), a report on information costs and the role played by export promotion agencies in which we carefully evaluated the myriad of programs offered by these agencies and provided a reliable road map for what works and what does not.

Too Far to Export, this present report, fits into this research effort aimed at broadening the region's trade agenda. The report revisits the issue of transport costs, this time with the mission of closing an important knowledge gap left by *Unclogging the Arteries*: the domestic transport costs to export. LAC's exporters face not only high costs to send their goods abroad, but also to ship them from factories, mines, and farms to the ports of exit. These domestic costs are particularly damaging to the less developed and more remote areas, which as a result often forgo valuable export opportunities.

This distributive dimension of trade costs is often overlooked by policymakers and researchers alike. But as the report shows, its implications can hardly be overstated. Bringing down domestic transport costs will ensure that LAC makes the most of its vast export opportunities and that gains from trade are more evenly spread within the countries. It is as much an economic as it is a political economy issue. Governments can hardly maintain support for free trade if benefits are concentrated in small, wealthy areas of the countries, as is presently the case in most, if not all, countries in the region. *Too Far to Export*, armed with hard-won data, argues that less costly access to domestic ports can go a long way in achieving trade equity.

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>> Overview 1

In Punta Arenas, Chile, at South America's southern tip, beer producers wishing to sell abroad must ship their product by truck to the port of San Antonio, in the country's central region, a distance of more than 1,800 miles. While this is a middle income region, local firms rarely export their products. Similarly, in Pucallpa, capital of Peru's low income department of Ucayali in the Selva region, exporters of wood products must ship their goods to the port of Callao, in Lima, over 466 miles of often unpaved roads that wind through the Andes, sometimes at elevations higher than 13,000 feet. Like the beer exporters of Punta Arenas, they are members of a rare breed of local firms in remote regions that venture to sell abroad.

The same holds true in Colombia's department of Meta, located in the center of the country. There, the exporters of metal products of Villavicencio usually have to ship their products to the port of Cartagena, 18 hours and 685 miles away.

In Mexico, exporters in Chiapa de Corzo, in the southern state of Chiapas, are scarcely the envy of their Chilean, Peruvian, and Colombian counterparts. Their powdered milk exports have to travel an average of 671 miles to reach ports on the Pacific and Gulf of Mexico, often having to cross mountain passes at elevations up to 7,400 feet, and then endure congested roads in the central region of the country. Understandably, exporters are rare in that region also.

Similarly in Brazil, long and costly shipments are also part of the challenge faced by soy exporters in the municipality of Sapezal in the Central West state of Mato Grosso. Most of their products are shipped through the congested port of Santos in the Southeast, 1,400 miles away.

These stories might be considered extreme and anecdotal, but unfortunately they largely reflect the reality confronted by most firms located in regions far from the main urban agglomerations and ports in Latin America and the Caribbean (LAC). Firms with the resources and skills to produce goods in high demand by regional or world markets face high domestic transport costs that destroy their competitive advantages, literally along the road. Or they refrain from exporting altogether. In many cases, prohibitive transport costs prevent them from even opening their business. As such, they are invisible to policymakers and researchers, but represent very real missed opportunities for regions that are usually at the bottom of the income distribution.

Why Should Governments Care?

This report is a part of an ongoing effort to increase LAC policymakers' understanding of the trade consequences of high transport costs. It follows the publication five years ago of *Unclogging the Arteries: The Impact of Transport Costs on Latin America and Caribbean Trade* (Mesquita Moreira, Volpe, and Blyde, 2008).

With *Unclogging,* our objectives were not modest. We wanted to radically change the region's trade policy agenda, and for a good reason. Our data, and that of a few pioneering studies before ours (Hummels, 2001 and Clark et al., 2004), were unequivocally showing that a massive shift had taken place in the relative importance of what economists call trade costs. Thanks to successful unilateral, regional, and multilateral trade liberalizations, traditional tariff and non-tariff barriers had been reduced to just a fraction of what they were decades ago. At the same time, transport costs, driven by historical underinvestment in transport infrastructure, had clearly followed an upward trend to become the most important obstacle to LAC's trade.

It was also clear that this shift had been compounded by the increasing fragmentation of world production, which places a premium on timelier and less expensive ways of shipping parts and components abroad. In addition, the region is increasingly specializing in transport intensive commodities and manufacturing goods as a result of China's emergence into the world economy.

Unclogging shed considerable light on the consequences of LAC's high international freight costs and on the impressive payoff of policies that could bring them down. But it dealt with just part of the problem. Data constraints meant that the other key component of the logistic chain—domestic transport costs—had to be left out of the analysis. As the examples cited above suggest, this component is essential for grasping the overall dimension of the problem. Yet studies or surveys looking at the domestic transport costs of exporting are rare, usually restricted to a few countries or products, and more often than not rely on qualitative information.[1]

This study makes a concerted attempt to fill this knowledge gap on the domestic side of transport costs, despite the continued existence of severe data constraints. Once we step inside international borders, we immediately see that the impact of shipping costs goes beyond the level and diversification of a country's exports. They also matter for determining which subnational region gets the chance to leverage trade to drive economic growth.

High domestic transport costs can push exports to concentrate in just a few areas with facilitated access to customs, while squeezing gains or simply locking out of trade large swaths of the country. This can be particularly costly for countries with large regional disparities and where labor and natural resource endowments vary significantly across the regions, creating a wealth of comparative advantages and export opportunities. Such a description fits many, if not most, LAC countries.

[1] See, for instance, Matthee and Naudé (2008), Granato (2008), Costa-Campi and Viladecans-Marsal (1999) or Nicolini (2003).

A Knowledge Gap Full of Challenges

Any serious analysis of the trade consequences of domestic transport costs faces formidable empirical, theoretical, and policy challenges. The first hurdle comes from establishing the origin of exports and measuring their shipment costs to the customs of exit. As in most parts of the world, LAC firms normally list their headquarters as the source of their exports, which is not necessarily the place of production, with the result of inflating the export share of large cities. Moreover, with a very few exceptions, domestic freight rates are not systematically surveyed in the region, which leaves the researcher with no reliable database with which to work.

Once these data obstacles are overcome, the challenge remains of establishing causality. The relationship between transport costs and exports is not a one-way street. Intuitively, it would seem that lower transport costs would have a positive impact on exports. But a high volume of exports that produces economies of scale in transportation is also likely to lead to lower transport costs. The two-way nature of this relationship requires researchers to look beyond correlations to avoid overestimating, for instance, the benefits of building a new road or railway for a region's exports.

Finally, to cap it all, economic theory offers some guidance, but few certainties, about this complex relationship between transport costs, trade, and regional disparities, making it difficult to draw broader policy implications. Among the few certainties is the benign, if not linear, economic geography view of the relationship between transport costs and the location of economic activities, which is assumed to follow a bell-shaped curve. When transport costs are too high, disparities tend to be low because there is little trade among mostly autarchic regions,which forgo the scale and specialization gains of trade. As these costs fall, internal trade develops and agglomeration and scale economies tilt locational incentives towards the wealthiest regions, which increases disparities. However, as transport costs fall further and congestion and higher land and labor costs reduce the advantages of the "center," firms start moving production back to the "periphery," improving the spatial distribution of economic activity.[2]

[2] See Combes, Mayer, and Thisse (2008) for a recent review of these arguments.

The consensus around this view breaks down when international trade enters the picture, particularly in the context of trade liberalizations. Theorists generally fall into two camps: those who believe that international trade increases regional disparities, because wealthy regions are more likely to thrive in a more competitive environment; and those who argue that this is not necessarily the case, because greater access to world markets weakens the gravitational pull of these regions.[3]

This divide becomes less of a concern, though, once we realize that it arises from models more appropriate to the European experience; in that continent, subnational regions do not significantly differ in either resource endowments or in the stock of transportation infrastructure. For example, Behrens (2011) shows how differences in domestic transport costs tend to play a decisive role in how international trade impacts regional disparities. In his analysis, countries with greater subnational variance in the stock and quality of their transport infrastructure are shown more likely to experience divergence. This type of world seems to be much closer to the reality of most LAC countries and provides a good framework for understanding the general trade implications of transport policies and the forces behind the region's mixed experience with regional convergence after trade liberalization.

There is clear evidence in the region that deconcentration of economic activity has taken place after trade liberalization, particularly as regards exports. However, this process of deconcentration does not seem to have gone far enough to support a fast convergence of regional per-capita incomes in countries such as Chile, Peru, and Colombia; nor has it prevented the worsening of regional disparities in Mexico, where this worsening has only recently begun to be reversed; nor has it even made an impact on Brazil's regional disparities.[4] Our working hypothesis is that at least part of this

[3] See, for instance, Monfort and Nicolini (2000) for the divergence view, and Krugman and Livas Elizondo (1996) and Behrens et al. (2007) for different forms of the convergence argument.

[4] See Serra et al. (2006) for data on LAC's subnational per-capita convergence post-trade liberalization, and the country chapters of this volume for data on export concentration.

puzzle can be explained by the region's failure to bring domestic transport costs down from the top of the bell curve, leading countries to forego export opportunities made possible by their wide subnational variation in natural resources and labor endowments.

Overcoming the Data Challenge

We set out to meet these challenges by building an unprecedented database of the origin and domestic shipping costs of exports. In both areas, we found workable solutions to get around the data constraints without having to sacrifice too much in terms of reliability and the certainty that we could put together a strong sample of some the largest and more representative countries in the region. The sample includes Brazil, Chile, Colombia, Mexico, and Peru, which in 2012 accounted for 71 percent of LAC's exports, and whose case studies are the subject of the following five chapters of this report.[5]

In an effort to minimize the headquarters bias and identify the actual municipal origin of exports, we adopted different strategies to make the most of available data in each of the five countries studied. In Chile and Mexico, we combined customs transaction data with comprehensive firm directories. In Peru, we limited ourselves to customs transaction data that (unlike in the other countries) provided information on both the municipal origin of exports and the firms' fiscal residence, each of which show markedly different spatial distributions of exports. In Brazil and Colombia, where we worked with more aggregated, product level information, we used municipal census information to validate the customs data. Whereas distortions may remain, we are confident that we have a much better picture of the reality on the ground.

To estimate the costs of shipping exports from the municipality of origin to the customs of exit, we used georeferenced data on operating expenses of cargo vehicles throughout the transport network, a methodology borrowed from Combes and Lafourcade's 2005 study of transport costs in France. Relying on data from national transport

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[5] IMF Direction of Trade.http://elibrary-data.imf.org/

service surveys and logistics plans, we built a measure of route and vehicle- specific transport costs that includes both time (e.g., labor, depreciation, and insurance expenses) and distance costs (e.g., fuel and maintenance expenses); this information reflects the profile of the countries' fleets and the quality and topography of the routes. With the help of geographical information system software, we used these estimates to compute overall transport costs on the least costly export routes for each municipality. Finally, to gain a better sense of the impact of these costs on the final price of the product, we built an ad valorem measure, dividing the transport costs in the least costly routes by the value of exports.

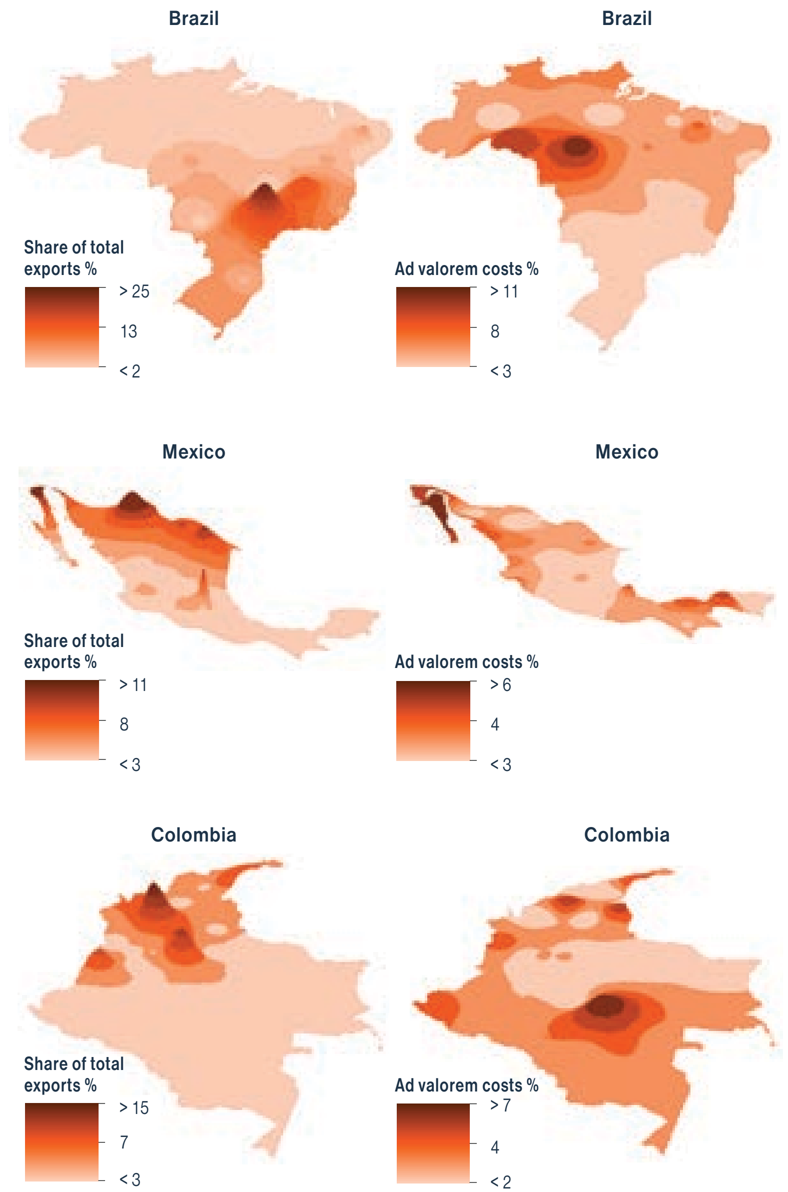
We made small variations in this methodology in each country to accommodate data availability, as explained in the technical appendices of each chapter. For all countries except Brazil we had to limit our analysis to road transportation. However, the representativeness of the analysis did not suffer significantly since trucks account for an average 80 percent of the cargo transportation in these countries.

A Story of High Concentration Where Transport Costs Are Low

The first major feature of the data is the high spatial concentration of exports, which is readily seen in the maps in the left-hand column of Figure 1. Concentration tends to be even higher at municipal levels, where generally only a minority of firms in relatively small and wealthy areas of the countries manage to export (Table 1). Chile and Mexico diverge somewhat from this description: in the former, the majority of municipalities (*comunas*) export, and these cover a significant part of the national territory; in the latter, exporting municipalities are also more spatially dispersed. But in both countries, exports are heavily concentrated in the top municipal exporters.

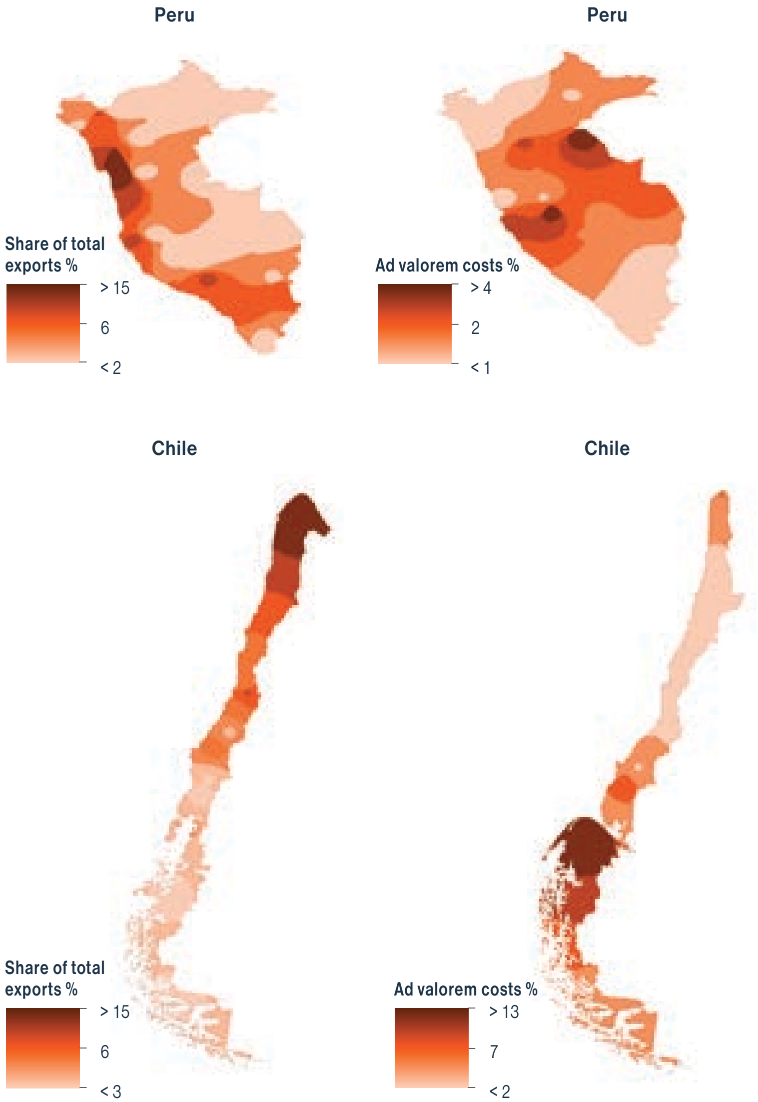
The data's second and particularly revealing feature is the inverse correlation between the unequal spatial distribution of exports and domestic transport costs. A first glimpse of this relationship can be seen in Figure 1, where the maps in the right-hand column show how domestic ad valorem freight rates to export vary within countries. A quick comparison with the

FIGURE 1 ■ Spatial Distribution of Exports and Ad Valorem Transport Costs to Export: Brazil, Mexico, Colombia, Peru, and Chile



Continued on next page

FIGURE 1 ■ Spatial Distribution of Exports and Ad Valorem Transport Costs to Export: Brazil, Mexico, Colombia, Peru... (*continued*)



Source: Own estimates based on the countries' customs data and transport surveys.
Note: This figure shows contour maps of the spatial distribution of exports, based on the state's (or administrative unit equivalent) share of total exports, and their ad valorem transport costs to export. Each elevation (hue) represents a different level of export share or ad valorem costs. Data for Brazil is from 2010; Mexico, 2012; Colombia, 2006; Peru, 2009 and Chile, 2008. See country chapters for details on the underlying data.

Table 1. Selected Indicators of Municipalities that Export

	Number and Share of all Municipalities	Share of the Country's Area (%)	Top Ten's Share of All Exports (%)
Brazil (2010)	1,055 (19%)	27	55
Chile (2008)	242 (69%)	57	74
Colombia (2006)	269 (24%)	11	73
Mexico (2012)	969 (39%)	69	68
Peru (2009)	451 (24.5%)	36	45

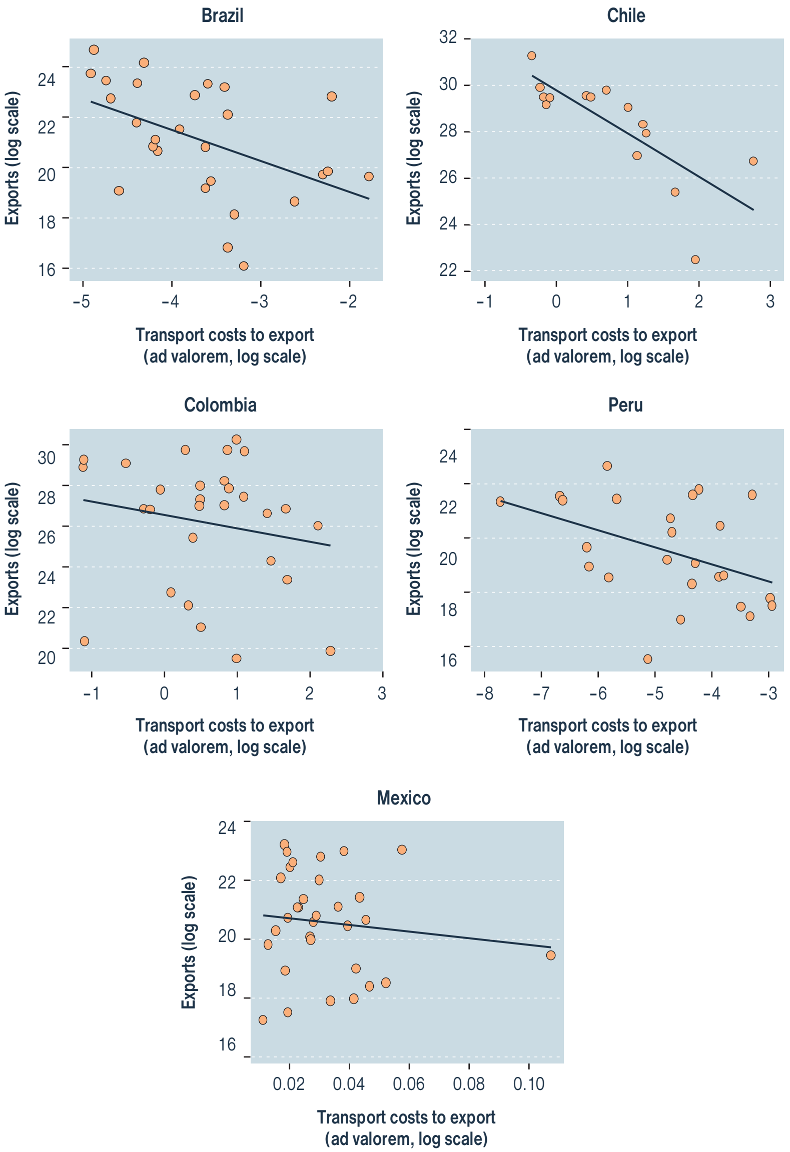
Source: Authors' estimates based on the countries' customs data. See country chapters for details.
Note: This comparison suffers from the variation in the size of municipalities. It should be viewed as a first approximation.

export concentration maps in the left-hand column shows that the areas with the highest costs are those with the lowest shares of the countries' exports. This can be seen more formally in Figure 2, which plots the states' exports against their ad valorem transport costs.

The magnitude of these costs is in itself revealing, but in less intuitive ways. On average the costs are generally low, ranging from 3.4 percent in Chile to 5.5 percent in Brazil, but with a significant variation across countries and municipalities, as can be seen in Figure 3. These low averages can give rise to misleading interpretations as to their relevance. It is important to remember that, as mentioned earlier, we are just looking at operational costs, leaving aside the markup charged by cargo providers. This markup can be particularly steep in remote regions where there is little to no competition. In the only instance where we could collect data on market freight rates (soy exports in Brazil, see Chapter 1) our measure proved to be highly correlated, and, as expected, systematically lower than market rates. We are also leaving aside other important components of logistic costs such as warehousing or route congestion, which are particularly significant at the port of exit for most LAC countries.

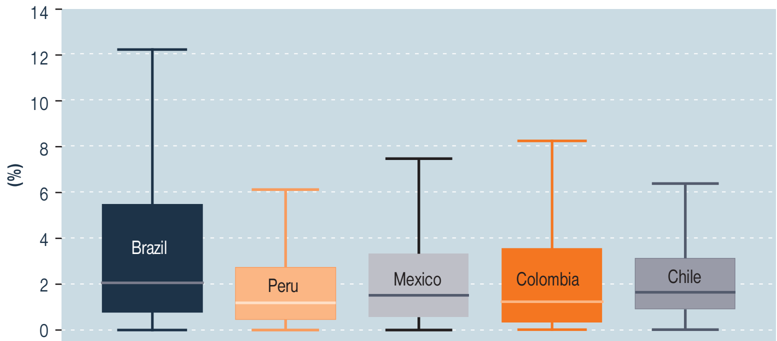
Perhaps more important is the fact that transport costs in the remote and peripheral regions are likely to be so high that potential exports are usually priced out of the market, exceptions being a few areas with extraordinary comparative advantages, such as the soy producing region in Brazil's Central-West. If exports never reach the market, we cannot observe their costs, which might lead to an underestimation of the trans-

FIGURE 2 ■ State's Exports and Ad Valorem Transport Costs
Brazil, Colombia, Chile, Peru, and Mexico



Source: Own calculations.
Note: This figure plots the countries' state exports (or administrative unit equivalent) in a given year and the average municipal ad valorem transport costs to export in each state (i.e., shipment costs from municipality of origin to customs of exit). Brazil's data is for 2010; Colombia's, 2006; Chile's, 2008; Peru's, 2009 and Mexico's, 2010. See Technical Appendices of each chapter for details.

FIGURE 3 ■ **Municipal Ad Valorem Transport Costs to Export**
Descriptive Statistics. Brazil, Colombia, Chile, Peru, and Mexico



Source: Own calculations.
Note: This figure presents descriptive statistics of the municipalities' (or equivalent administrative unit) ad valorem transport costs using a box plot. The median value is represented by a line subdividing the boxes. The length of the boxes represents the "interquartile range (IQR)", which includes values between the 25th quartile (lower hinge) and the 75th quartile (upper hinge). The lines (whiskers) are drawn to span all data points within 1.5 IQR of the upper and bottom hinges. Brazil's data is for 2010; Colombia's, 2006; Chile's, 2008; Peru's, 2009, and Mexico's, 2010. See Technical Appendices of each chapter for details on data building.

port costs in these regions. We only take into account the costs below a certain threshold, above which no export activity takes place.

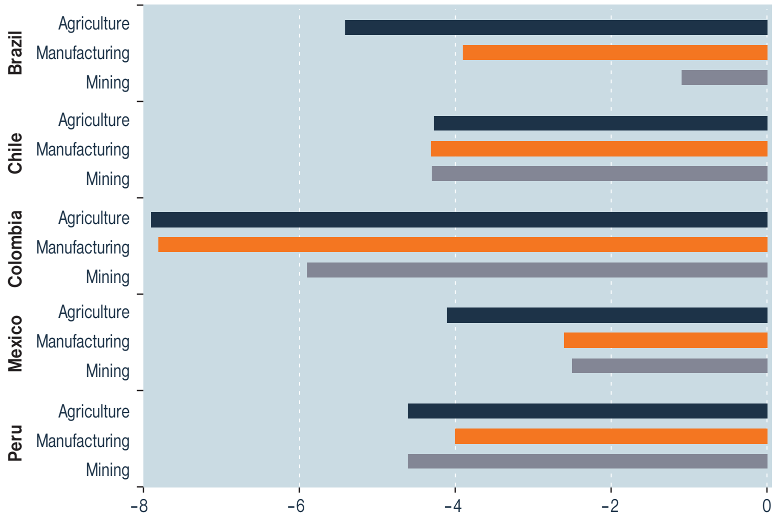
What Is the Impact on Exports After All?

This inverse relationship between exports and domestic transport costs suggests that policies tailored to lower these costs are likely to have a significant impact on exports, particularly in areas where access to ports is most costly. However, more than simple correlations are needed to make a precise estimate of this impact given the many factors at play in addition to transport costs. These factors range from comparative advantages to government intervention to historical accidents.

We sought to isolate the role played by transport costs by estimating an equation that relates municipal exports at the product level with their ad valorem transport costs to the customs of exit, while controlling for the influence of factors that might also affect exports, as follows: permanent characteristics of the municipalities (comparative advantage and institutions), products (dimension and transportability), and customs (port specialization). We also made sure that our results were not biased by unusual events during the study period. Since the impacts of transport costs are likely to vary significantly across types of products due to differences in transportability (Hummels, 2001), the estimations were made by broad product categories—manufacturing, agriculture, and mining.

The results (contained in Figure 4 and discussed in more detail in the country chapters) confirm the inverse correlation of transport costs with level of exports and point to an economically and statistically significant impact in all five countries studied. Colombia emerges as the country with the most to gain from improvements in transport infrastructure and services: a 1 percent reduction in ad valorem transport costs can increase exports by as much as 7.9 percent in agriculture, 7.8 percent in manufacturing, and 5.9 percent in mining. But even Mexico, where average impact across sectors was the lowest, would see substantial gains

FIGURE 4 ■ The Impact of Transport Costs on Exports by Sector and Country



Source: Author's calculations.

Note: Results are statistically significant at 1%.For Chile and Peru, agriculture and mining share the same coefficient as they were jointly estimated.See the technical appendices of the countries' respective chapters for details.

through improved transport, particularly in agriculture, where a 1 percent drop in transport costs could produce a 4 percent increase in exports.

Although these results are a significant step beyond correlations, they should be still regarded as rough estimates for at least three reasons. First, by focusing on exports, we are not capturing indirect effects of transport costs on production. Atack, Haynes, and Margo (2010), for example, are among the few to estimate this type of effect. They found that lower costs of rail transport in the second half of the 19th century accounted for as much as a third of the increase in the number of manufacturing establishments in the areas of the US that benefited from those rail investments.

Second, the figures miss the impact of transport costs on municipalities that do not export, because, by definition, we cannot observe the products they would export nor the customs of exit they would choose. As mentioned earlier, these are most likely the municipalities where transport costs are so high that they do not export at all.

Finally, there is the issue of reverse causality mentioned earlier. Higher levels of exports are likely to lower transport costs by increasing economies of scale and encouraging investments in infrastructure. If these effects are significant in the cases we analyzed, our estimates are overstating the impact of transport costs.

We assessed the extent of these potential biases through a number of different strategies designed to accommodate differences in the countries' data availability. The most highly developed strategy was applied in Chile, where we used the impact of the powerful 2010 earthquake on the country's roads as a natural experiment (Box 1, Chapter 2). In the other countries, we replaced transport cost by variables that are correlated with it but that are not affected by the level of exports, such as the Incas' road network in Peru (Box 1, Chapter 5), or the straight line distance to the customs of exit in the cases of Brazil, Colombia, and Mexico (that is, assuming there is no topographic or network impediment between origin and destination). For the most part, the results do not suggest a significant bias in our results.

In countries such as Brazil, Mexico, and Peru, we also looked at the impact of transport cost on the municipalities' probability to export in an effort to address the lack of non-exporting municipalities in our sample. Again, the results suggest that this impact might not be large enough to seriously question the accuracy of our estimates.

Apart from estimating the impact of transport costs on the value of exports, we also assessed their effects on the number of products exported by municipalities for some of the countries in the sample. Overall, even if we consider the upper bound of these estimates, the impact is significantly lower than that on the value of exports. The effect on number of products is greatest in Peru, where a 1 percent drop in transport costs would lead to an average increase of 2.9 percent in the number of products exported. The effect is significantly lower for Brazil and Mexico, where average increases are below 1 percent.

Bringing the Discussion Closer to Actual Policies

To move this discussion closer to the world of policymaking, we used these estimates and our georeferenced database to simulate the impact on exports of straightforward measures to lower domestic transport, some of which are already being implemented by governments in the region. As with most of the previous analysis, we adapted the simulations to the data and policy realities of each country in the sample. In Brazil and Peru, we combined government projects to expand the transport networks with ad hoc measures to improve their quality. In Mexico, we focused on the investment projects of the 2007–2012 Road Program. In Colombia and Chile, we simulated a regional cost convergence to a benchmark defined by the municipalities with the lowest transport costs.

The overwhelming message that emerges from these exercises is that policies to minimize domestic shipping costs can be particularly powerful in reshaping the subnational distribution of exports and spreading the gains of trade more evenly. In Peru, for instance, we estimate that building new paved roads has the most impact on the Selva and Sierra departments, which are among those that export the least. Their domestic shipping costs would drop 15–40 percent and exports would increase 10–23 percent. Ucayali, whose capital Pucalpa was the subject of one of our eye–opening stories, is among this group, with most of its benefits coming from the conclusion of the Central Interoceanic Highway, which connects the department to the port in Lima.

In Brazil, implementation of the National Logistic Plan's major railway and waterways projects and an overall improvement in road quality are estimated to benefit disproportionately the country's remote agricultural and mining regions, particularly in the North and Central-West. These investments would reduce average domestic shipping costs in these areas by 30 percent and would boost exports by an average of 12.5 percent. The exporters of Sapezal, who face long and costly shipments, would particularly benefit from better rail (the Transcontinental Railway) and waterway (Tele Pires-Tapajós) links to the ports, with transport costs falling by 30 percent and exports growing by nearly 40 percent (or US$ 860 million, using 2010 figures).

In Mexico, even though the 100 strategic projects of the road program do not particularly seem to target the peripheral regions, some of these regions' states appear among the greatest beneficiaries. In Chiapas in the South, for example, the exporters of Chiapa de Corso enjoy a modest drop in shipping costs (6 percent), but a substantial 20 percent increase in exports due to a combination of higher capacity and new roads.

In Colombia, a countrywide convergence in domestic transport costs to the level enjoyed by a department such as Magdalena in the North—whose costs are among the lowest 25 percent in the country—would have the most impact in the remote and poorer regions. Among the most to gain are in the Southeast, the Center and some of the states of the Pacific region with average foreign sales increases between 10 and 45 percent. The department of Meta, the home of the logistically constrained exporters of Villavicencio, would see its foreign sales increase by as much as 11 percent.

Finally there is Chile, where a countrywide convergence in domestic transport costs to the level of Santiago—one of the lowest of the country—would produce dramatic transport cost savings in the most remote and least export-oriented regions of up to 80 percent and increases in exports of up to 40 percent. For example, in Magallanes, the region of the persistent beer exporters of Punta Arenas, exports would grow by an average of 18 percent.

Addressing the Obvious: Easier Said than Done

This report can be plausibly accused of stating the obvious, but hopefully not in incomprehensible terms—a charge usually levied at economists.[6] It is certainly obvious to LAC exporters on the ground that transport costs these days are a much more important impediment to their business abroad than the proverbial tariff and non-tariff barriers. You just have to ask firms in Punta Arenas, Pucalpa, Villavicencio, Chiapa de Corso, or Sapezal. However, individual exporters can rarely see the forest for the trees, and this perception has been slow to translate into policy action. This translation also hinges on good data and, unfortunately, there has not been a systematic effort in the region to collect information and rigorously assess the trade implication of transport costs. This is where this report, and *Unclogging* before it, endeavored to make a contribution.

Without solid data it is hard to grasp the whole dimension of a problem no matter how obvious it may appear. By making this initial effort to measure and analyze the impact of domestic transport costs, we have drawn attention to the highly uneven subnational distribution of the gains of trade, an important dimension of LAC integration into the world economy that is often overlooked. We have also shown that shipping costs are likely to be a key part of this problem and that policies targeted to reduce these costs—particularly in the more remote, often poorer—regions, offer a hefty payoff in export opportunities.

Some would argue that the high spatial concentration of LAC exports might be an "efficient" result, because productivity tends to be higher in the big cities.[7] We disagree. It just takes a day in the intractable traffic of São Paulo, Mexico City, or Bogota to realize that we may have far exceeded the optimal levels of urban agglomeration and that the dispersion forces might have been weakened, among other things, by the poor transport infrastructure outside the big urban centers. Moreover,

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[6] Alfred Knopf, a well-known American publisher of the second half of last century, once reportedly said, "An economist is a man who states the obvious in terms of the incomprehensible."

[7] For arguments along these lines see World Bank (2009) and Glaeser & Gottlieb (2008).

since in many, if not most, LAC countries, natural and labor resources are widely dispersed across their territories, high transport costs tend to impose severe restrictions to their export potential.

At the risk of stretching a comparison too far, most LAC countries seem to have yet to go through the type of transport revolution experienced by the US in the 19th century. In that country, a strong transport network helped to disperse economic activity and transform the formerly remote Midwest into a leading exporter of agricultural and industrial goods, as was chronicled by Fishlow (1965). As Fishlow argues, transportation was neither necessarily the leading nor the only factor behind those changes, and he was particularly leery of the idea that developing countries could replicate the US experience just by investing in large-scale transport projects, all too common (and often poorly designed) in LAC in the 1960s and 1970s. But the fact remains that without the network of canals and railways built during that period such transformation would not have been possible.

Nevertheless, it would be naïve to think that filling the data gap and raising awareness of the trade consequences of high transport costs would be sufficient to prompt governments into more effective action in meeting the challenges they face. In fact, since *Unclogging* was published five years ago, there have been promising signs that LAC policymakers are starting to look beyond trade agreements. Improvements in transport and logistics are increasingly part of the trade policy discourse, and regional and national logistic plans or initiatives seem to be on their way to becoming a must-have for governments in the region.

For example, we can cite the national logistic plans of Brazil or Chile, Mexico's road program, Peru's interoceanic highways, and regional initiatives such as the Initiative for the Integration of Regional Infrastructure in South America or the Mesoamerica Project, both of which have been thoroughly supported by the IDB.[8] Yet, progress in executing these plans and reducing transport costs has been painfully slow.

A detailed answer to why the process has been so slow is beyond the scope of this report. Overall, however, it can be said that in the countries

[8] For details see http://www.iirsa.org/ and http://www.proyectomesoamerica.org/.

studied the major issue is underinvestment, particularly in cheaper and alternative modes of transportation such as rail and waterways. The reason for such underinvestment is not only budget constraints, but choices made in public spending priorities and institutional and regulatory weaknesses.

Reliable and updated data on LAC investments in transport infrastructure are elusive. The last serious effort made to estimate these figures, which used information up to only 2006, indicated that investments are recovering, but that levels still remain below 1 percent of the GDP; this is disappointing even by the dismal standards of the 1980s (Calderon and Serven, 2010). Nor there are signs that the situation improved significantly over the intervening seven years. The region's countries have continued to perform poorly in traditional indicators such as road and rail density, the percentage of roads paved, port transit times, or qualitative indicators based on perceptions.[9]

The performances of Brazil and Mexico, two of the few LAC countries where recent investment estimates are available, seem to corroborate this point. Even though the size of their territories makes investment in transportation a no-brainer, their investments have represented less than 1 percent of their GDP over the last five years, despite having announced a series of ambitious transport infrastructure plans. This amount is less than half of their historical peaks and one-fourth China's average in the last decade.[10]

Underinvestment forces governments into an unforgiving tradeoff: addressing maintenance and congestion at the center, or developing the infrastructure in the periphery. The region's experience shows that neither of these two objectives ends up being satisfactorily addressed, and this is particularly damaging for the export prospects of the periphery.

Even though budget constraints are part of this story, it does not seem to be the only or even the dominant cause for underinvestment, particularly considering the improvements in the region's fiscal condition

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[9] For example, see the World Bank's Logistical Performance Index. (http://data.worldbank.org/indicator/LP.LPI.OVRL.XQ) and World Economic Forum's Global Competitiveness Index, Transport infrastructure. http://www.weforum.org/issues/global-competitiveness.

[10] See Chapters on Brazil and Mexico and McKinsey (2013) for the figures on China.

in the last decade. In some countries, for instance, there are legitimate questions to be asked about public spending priorities, given the substantial resources being devoted to what can be generally described as "industrial policy," whose effectiveness to boost exports or address regional inequalities is questionable at best.

There are also strong signs that most countries are struggling to implement their investment programs, as in Brazil, Mexico, Peru, and Colombia. The unifying theme seems to be that public institutions face difficulties in designing, evaluating, and executing investments in transportation. Part of this weakness reflects centuries of neglect, but is certainly aggravated by the ravages of the fiscal crisis of the 1980s that led to a severe brain drain in the public sector. In some cases, decentralization of transport investments to local governments without the necessary institutional resources added to the problem. These weaknesses in design and execution have taken a particularly severe toll on the connectivity of transport networks in the region, preventing local firms from taking advantage of the multimodality to lower their transport costs.

These institutional limitations also undermine the development of a regulatory framework capable of leveraging private sector investments. To be sure, all countries in our sample managed to attract substantial private sector investment in road and rail concessions, with Chile leading the way. Yet in most cases, they are far from exploiting the full potential of private sector involvement. A number of challenges stand in the way, including lack of independence, technical expertise, and coordination among regulatory agencies; poorly designed contracts that lead to constant renegotiations; and misguided nationalistic policies that prevent foreign companies from competing in badly need services such as cabotage or air cargo.

It is also worth noting that given the existence of strong policy complementarities, policies to overhaul the transport infrastructure will be more effective in fostering exports if they are properly combined with other initiatives to reduce trade costs as a whole. This is particularly true in the case of trade facilitation and export promotion actions that address obstacles to completing administrative and logistic processes and gathering the information required to operate in international markets (Volpe Martincus, 2010).

Overall, there seems to be no shortage of good diagnostics for the transport impediment the region faces in boosting its exports. The challenge seems to be attracting enough financial, institutional, and managerial resources to address this issue. By offering estimates of domestic transport costs and their impact on regional export disparities, we hope to improve the likelihood of this happening. To put it simply, we hope to make clear to policymakers in the region what is already intuitively obvious to exporters on the ground: that to invest these resources to lower transport costs can bring substantial trade gains, while helping to mitigate costly and long-repudiated subnational disparities.

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>> The Elusive Obvious: Transport Costs and Brazil's Regional Export Disparities 2

With its 8.5 million square kilometers of territory, Brazil is the largest country in LAC and the 5th largest in the world. Its sheer size alone would dictate that domestic transport costs are a major factor in the country's economy as well as a key determinant of the relative benefits its different regions receive from foreign trade. But size is not the only factor that has affected transport costs in Brazil. Since the country's foundation, the transport infrastructure has not only developed at a slow pace, but it has also favored some regions more than others. More recently its deficiencies have been compounded by questionable modal choices and decades of underinvestment, and comparative advantages in transport-intensive natural resources have elevated their relevance to the policy equivalent of a "no-brainer."

Despite their importance, transport costs are often overlooked by economists and policymakers when considering ways to improve Brazil's often lackluster export performance or to maximize its spillovers. That is particularly the case at the regional level. The purpose of this chapter is to deepen knowledge of this important area by quantifying the critical role of the country's transport costs at the regional as well as the national level. It is not easy to make a meaningful analysis of the relationship between transport costs and exports. As discussed in Chapter 1 of this book, this relationship is obscured by ambiguities resulting from weaknesses in the underlying theory and the empirical challenges of establishing causality, which usually run both ways: from transport costs to trade, and vice-versa. The absolute dearth of reliable transport data only adds to the difficulties.

In order to better understand these complexities, we build and analyze a novel georeferenced dataset at the municipality level to assess the impact of transport costs on exports, including the payoffs of different policy options. While our analysis leaves a number of methodological difficulties and unanswered questions, the results suggest that considerably more attention should be paid to the trade consequences of Brazil's domestic transport policies.

A Brief History of Brazil's Spatial Development

Throughout Brazil's history, geography, transport costs, comparative advantage, and all-out government intervention have interacted to shape the spatial distribution of the country's economic activity. This distribution shifted constantly during the first four centuries after the arrival of the Portuguese in 1500. The heavily favored regions were those that had (a) comparative advantages in the world's most sought after commodities, and (b) low transport costs.[1] As a result, territorial occupation was mostly restricted to the coastal areas, beginning in the Northeast—Brazil's closest region to "mainland" Europe—and gradually moving south, following sugar, gold, and coffee commodity cycles. In this period, a very precarious transport infrastructure was built that was mainly intended to connect the commodity producing areas to the ports, but not to promote integration among them or open up the interior.[2]

In the early 20th century, the country's pattern of occupation stabilized and grew highly concentrated. São Paulo and the Southeast became centers of industry as the result of interrelated factors such as a coffee boom, the Great Depression, European and Japanese immigration, two

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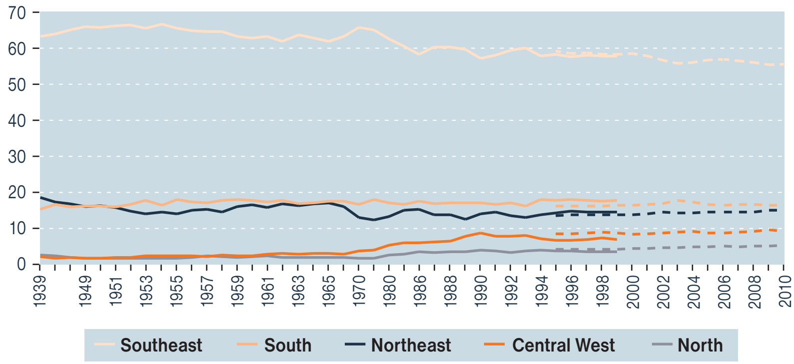
[1] Brazil is divided by the country's statistical office IBGE into five regions that include 26 states. See Figure Technical Appendix A.1.

[2] See Diniz (1987).

FIGURE 1 ■ Regions' Share of GDP. 1939–2010 (%)



Source: Solid lines series, IBGE Regional Accounts, old method. Dashed lines, IBGE Regional Accounts, new method.

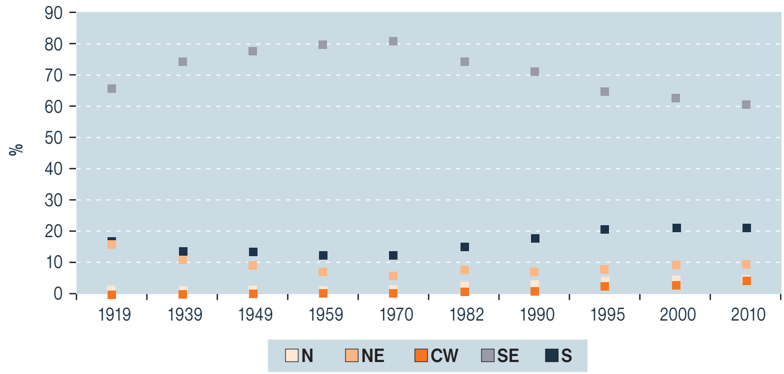
World Wars, and increasingly protectionist trade policies.[3] As a result of these developments, the Southeast's share of Brazil's GDP increased to 63 percent in 1939 even though the region represented only 10.8 percent of the country's territory; half of the Southeast's GDP share was accounted for by São Paulo. As shown in Figure 1, these high levels of regional concentration remained relatively stable over the following 70 years, although with a slight but clear downward trend, particularly after trade liberalization in the early 1990s. The expansion of the agriculture frontier to the Central-West was the main driver of this trend.

Data on manufacturing show a similar picture (Figure 2), except that regional concentration was even more pronounced; the Southeast's share of manufacturing value added peaked at 80 percent in 1973, with São Paulo alone accounting for 58 percent. In the late 1980s and early 1990s it was the South, and not the Central-West, that drove a modest deconcentration of manufacturing activity.

Brazil's current levels of concentration seem particularly high when compared to countries with territories of comparable size, such as the US (see Figure 3). In fact, Brazil's output concentration at the state level, when measured by the Hirschman-Herfindahl index (HHI), is approximately

[3] See Cano and Abreu, Bevilaqua e Pinho (2001).

FIGURE 2 ■ Regions' Share of Manufacturing Value-added. Selected years. (%)



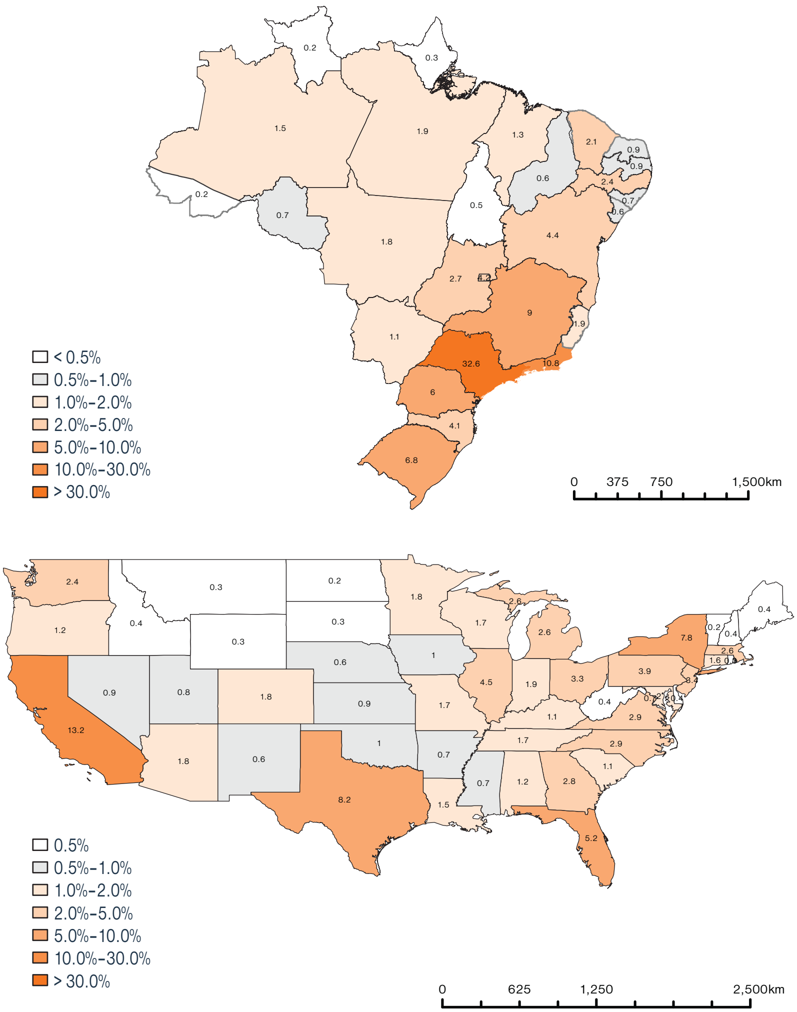
Source: From 1919 to 1970, IBGE Industrial Census as cited by Cano 1981; for 1982 and 1990, IBGE Annual Industrial Survey and for the rest of the period, IBGE Regional Accounts.

five times higher than that of the US.[4] This type of comparison is never perfect because of the obvious geographical dissimilarities (e.g., the US, unlike Brazil, borders two oceans) and political and historical differences. Yet, these differences do not seem to completely explain away Brazil's significantly higher levels of agglomeration.

This highly concentrated spatial distribution of economic activity corresponds almost perfectly to significant regional income disparities. As shown by Table 1, per capita income in the Northeast—Brazil's poorest region—is one third that of the Southeast, the richest region; this disparity has not changed significantly since the country's economy was opened up to trade 20 years ago. However, important changes did take place in the middle of the distribution, with the Central-West catching up with the Southeast. Here, the driving force was not only the expansion of the agriculture frontier, as mentioned before, but also the growing affluence

[4] The normalized HHI index varies from 0 (very low concentration) to 1 (very high concentration). In 2010, Brazil's index was 0.146 and that of the US was 0.028. This comparison might be seen as a rough estimate because the territorial size of the states varies between the two countries. However, even if, we use GDP data for comparable geographical units, as calculated by Yale's G-econ research project (http://gecon.yale.edu/) for 2005, Brazil's HHI is 60 percent higher than that of the US.

FIGURE 3 ■ States' Share of GDP. Brazil and the US 2009 (%)



Source: IBGE and BEA regional accounts.

of the Federal District, Brasilia, which is fueled by government spending rather than private sector activities. But even if Brasilia were omitted from the calculations, gains in the Central-West are impressive.

As expected, these production and income disparities are highly correlated with the distribution of trade flows across the country, particularly

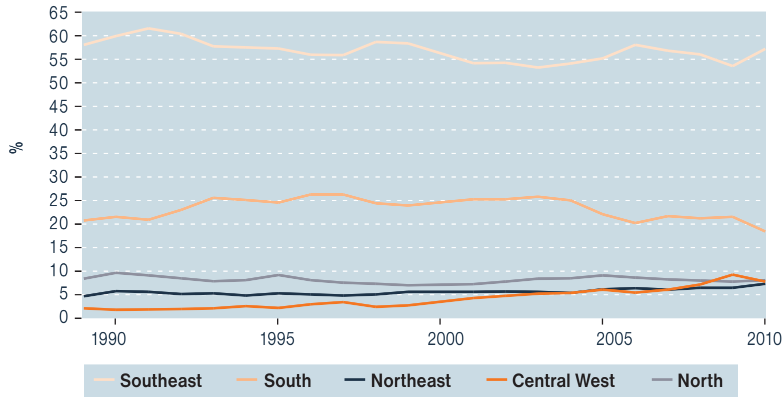
Table 1 ■ Brazil's Regional GDPs per capita: 1991 and 2010
Southeast = 100

	1991	2010
North	48.8	49.0
Northeast	33.5	36.8
Central-West	89.3	96.0
Central-West excluding Brasilia	49.5	67.2
Southeast	100.0	100.0
South	81.7	87.4

Source: Authors' calculation based on IBGE data.
Note: The two years are not strictly comparable because of changes in the national accounts methodology. See http://www.ibge.gov.br/english/estatistica/economia/contasnacionais/2009/default.shtm.

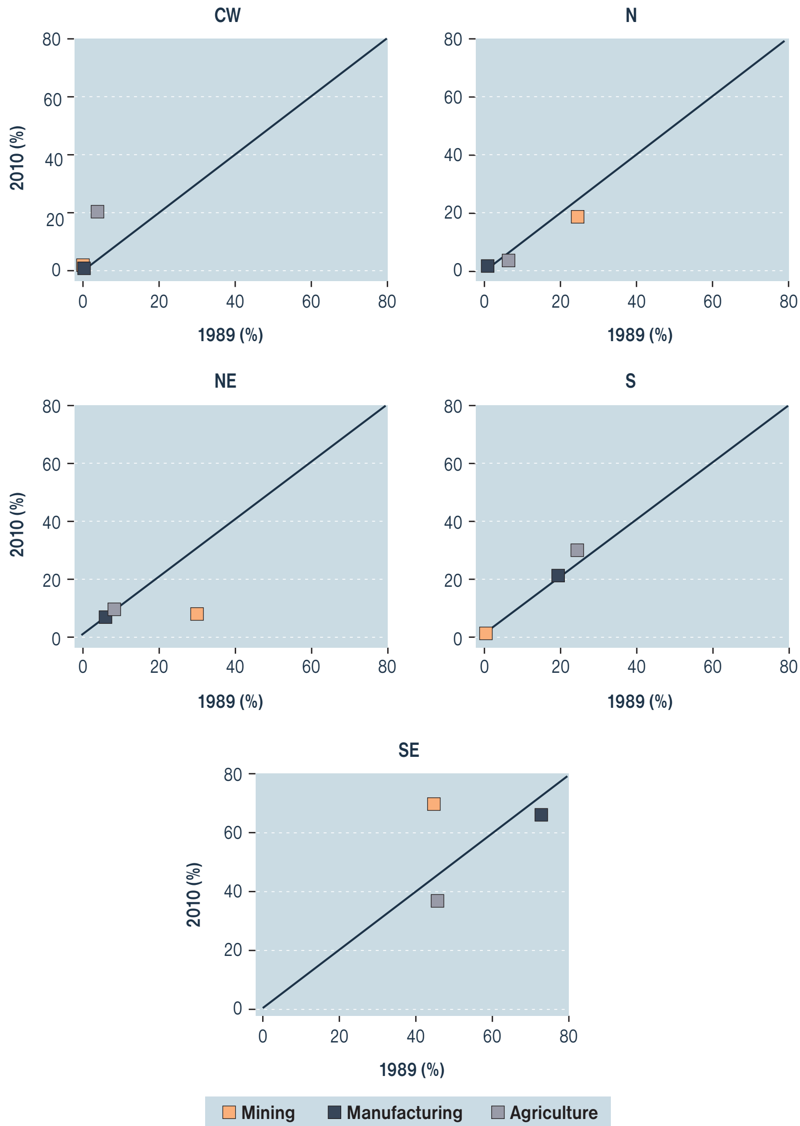
exports. As shown in Figure 4, the Southeast accounted for 57 percent of total exports in 2010, a share that has not changed significantly since the initiation of trade liberalization 20 years ago. As in the case of GDP and GDP per capita, the only significant change worth noting occurred in the Central-West, which quadrupled its share of total exports from 2 percent to 8 percent. Most of these exports were agricultural, which is consistent with the fact that agriculture was the only activity that showed noticeable signs of spatial deconcentration. There were also some significant

FIGURE 4 ■ Regional Share of Exports. Brazil, 1989–2010



Source: Brazil, Ministry of Development, Industry and Trade- Sistem ALICE.

FIGURE 5 ■ Regional Share of Exports by Category. Brazil 1989 and 2010



Source: Own calculation based on data from Brazil, Ministry of Development, Industry and Trade- Sistem ALICE.
Note: Categories defined using WTO definitions.

changes in mining, most particularly the Southeast's growing production of petroleum, which reinforced rather than diminished the region's dominant position (see Figure 5).

The Underlying Transport Infrastructure

This rapid and enduring spatial concentration of exports triggered by industrialization was initially supported by a transport infrastructure based on railways built and financed by private capital to serve coffee producers in the Southeast. These railways provided some connection among the main cities, but for the most part they connected producing areas with the ports. As such, they did not play a role in integrating less developed cities in the Center-West, North, and Northeast regions. As of 1936, close to 60 percent of the railway network was located in the Southeast.[5] The railways soon ran into serious financial problems partly due to the government's populist tariff policies and further compounded by the Great Depression.[6]

After the 1930s financial crisis, Brazil's transport policy shifted towards roadways, driven by significantly lower capital costs and greater flexibility. However, it was not until the early 1960s that the country's road network connected the main regional cities and offered industrialists a fully unified domestic market. Moreover, only 2.8 percent of this road network was paved.[7] The brisk pace of investments in roadways in the 1960s and 1970s quadrupled the paved network. Meanwhile, investments in railways dropped sharply, and the limited rail network even shrank during this period. Furthermore, few resources were directed to cabotage or waterways despite Brazil's long coastline and its wealth of rivers.

Brazil's debt and fiscal crisis in the 1980s brought its road boom to an end. Investments in transport infrastructure dropped to 1.5 percent of GDP, down from 2 percent in the 1970s. Investments in the sector fell even further in the 1990s to less than 1 percent. Such low investment

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[5] IBGE 1990.

[6] See Diniz op. cit.

[7] IBGE 1990.

levels compromised even the maintenance of the existing road network.[8] Recent estimates indicate a significant recovery of these investments in the early 2000s, driven particularly by public investments. But as of 2010, these investments still represented just 0.7 percent of the GDP, and they were heavily concentrated in roadways.[9]

This investment collapse took place well before Brazil could build a well-developed transport network. As late as 2011, only approximately 13 percent of the road network was paved, and road density was a mere 20 km of road per 100 km^2 of land area (compared to 42 km in the US).[10] The quality of the paved grid was also an issue, with 46 percent of the of roads suffering from "deficient pavement" (CNT 2012). These problems are most acute in the less developed regions. Road densities in the North, Central-West, and Northeast in the same year were 3.8 km, 6.6 km, and 28.5 km, respectively, well below the Southeast's 57.7 km. Furthermore, 91 percent of the roads in the North had deficient pavement, as did 70 percent in the Central-West and Northeast. In contrast, only 50 percent of the roads in the Southeast had deficient pavement.

Despite the shortcomings of the road network, trucks became the country's dominant mode of transportation, handling 70 percent of the domestic cargo freight in the early 1970s, then dropping to around 60 percent in the 1980s as the result of several railway projects built to transport iron ore for exports. The latest estimates (2011) put roadways at 52 percent, followed by railways at 30 percent, waterways 13 percent, and pipelines at 4 percent. In comparison, roadways carried only 31 percent of the US total freight in 2009, behind 37 percent for railways, 21 percent for pipelines, 11 percent for waterways, and 0.3 percent for air cargo.[11]

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[8] Bielschowsky et al. (2002).

[9] Campos Neto and de Moura (2012). In 2011, roadways accounted for 77 percent of the federal government's disbursed investments in transport.

[10] DNIT, Plano Nacional de Viação 2011 (*http://www.dnit.gov.br/plano-nacional-de-viacao*) and US Census Bureau Statistical Abstract 2012. Data for the quality of the pavement is from CNT (2012).

[11] PNLT 2012 and US Bureau of Transportation Statistics, National Transportation Statistics. In the case of Brazil, the estimate does not include air cargo, but this share seems to be residual, estimated at 0.3 percent in 2005 (PNLT 2009).

The Transport-Disparities Link

It seems reasonable to assume that the development of this slow, road-based, and regionally concentrated transport infrastructure has played an important role in creating Brazil's high levels of economic spatial concentration. In doing so, it appears to have resulted in at least two effects. First, as suggested by influential economic geography models, the relationship between regional disparities and transport costs seems to follow a bell-shaped curve in which disparities are low at points where trade costs are very high or very low and reach a peak when those costs fall into an intermediate range.[12] In Brazil, the development of transport infrastructure seems to have placed trade costs precisely at the intermediate range: not high enough to stop the formation of a national market, but not low enough to prevent the Southeast's economies of scale and agglomeration from dominating the centrifugal forces of lower land and labor costs in the less developed regions. This interpretation can be particularly useful for understanding the manufacturing sector's high and persistent levels of spatial concentration.

A second effect of Brazil's regionally biased development of transport infrastructure is more relevant to sectors such as agriculture and mining. In this case, such "intermediated" transportation costs are likely to have discouraged investments in high weight to value goods such as grains and minerals, particularly in the more remote North, Center-West and Northeast regions.

The combination of these two effects may help to explain not only why concentration increased sharply in the early period of industrialization, but also its modest decline after trade liberalization. The relationship between trade and regional disparities is still an open and complex question in the literature. But all other things being equal, there are at least three strong reasons to expect greater spatial deconcentration after Brazil's trade liberalization. First, protection discouraged exports, drawing resources away from the less developed regions that had clear comparative advantages in agriculture, mining, and labor intensive manufacturing as well as greater proximity to developed markets. Second, higher protection for manufacturing distorted relative prices to the detriment of primary activities—which

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[12] See e.g., Combes, Mayer and Thisse (2008).

dominates GDP in the less developed regions—forcing producers to buy local inputs well above international prices. And third, protection is likely to have dampened the response of firms to factor prices, since they could be based in the more expensive regions; charge prices well above international levels, and still dominate what was mostly an oligopolistic domestic market.

How the undoing of these distortions eventually plays out depends on a number of factors, not least how the stock of human capital is distributed across regions and the quality of the region's institutions. However, as illustrated by Behrens (2011), the higher the country's domestic transport costs are (short of prohibitive), the more likely it is to experience regional divergence as a result of the impact of these costs on firms' and workers' incentives to agglomerate.

While theory would indicate a prominent role for transport costs in Brazil's spatial developments, there is clearly a dearth of hard empirical facts to corroborate this conclusion. Castro et al. (1999) and Castro (2002) offer some of the best evidence available. The first study estimates the impact of logistic costs on interstate trade in the mid-1980s and finds negative elasticities between –1 and –2 (i.e., a 1 percent increase in transport costs reduces trade by 1 or 2 percent), with the negative impact increasing more for states with higher shares of agricultural GDP and longer transport routes. The second study estimates the impact of transport costs on agriculture output for 1970–1996 and shows that the Central-West region, whose emergence as an agricultural powerhouse in the late 1970s and early 1980s coincides with its access to a paved road network, has the greatest and most robust sensitivity to transport costs, with elasticities ranging from –0.4 to –0.9.[13]

[13] It is also worth noting the work done by Haddad, Domingues, and Perobelli (2002), World Bank (2008, Chapter 3), and Fally, Paillcar, and Terra (2010). The first paper uses a CGE model to simulate the impact of different scenarios of preferential and unilateral trade liberalizations. It concludes that the impact on exports tends to slightly favor the less developed regions. But this is reversed at the output level, where the South and Southeast benefit the most. The second paper also uses a CGE, but explicitly looks at the interaction between trade liberalization and transport costs. Here, the results show that reductions in transport costs magnify trade liberalization gains, which are shown to favor sectors that are intensive in land and unskilled labor. The third paper takes a partial equilibrium approach to estimate the impact of market and supplier access on wage differentials across Brazil's states and industries in 1999. They find that those variables explain 38 percent of the wage disparities across states and industries.

These exercises do not address reverse causality, i.e., that the expansion of output and trade might have led to lower transport costs. Nor do they adequately account for other factors such as agricultural subsidies and technological advances, which are likely to have played an important role in the Central West. Yet, they are the best indication so far of the role of transport costs in Brazil's recent spatial developments.

A Closer Look at Export Disparities

We strengthen this limited evidence base by taking a closer look at the role of transport costs in export disparities, working with data on products and municipalities. Domestic transport costs affect the municipalities' ability to export on two levels: (a) what and how much they produce, and (b) what and how much they export. Given the data constraints for addressing the first question (finely disaggregated output data for municipalities for a reasonable timeframe is not available), we focus on the second question. That is, we look at the impact of domestic transport costs on the municipality's ability to export a particular set of goods that are produced locally. This approach most likely leads to an underestimation of the impact of transport costs, but at least it brings us closer to assessing their true impact.

In evaluating this impact we face two different data challenges: establishing the origin (municipality) of the exports and cost of transporting them to the customs of exit. On the origin side, Brazil's Internal Revenue Service, the primary source for trade data, has reliable information on the state of origin, but not the specific municipality. Municipal data is biased towards the largest cities, particularly in the Southeast, because firms tend to report their headquarters as the origin of their exports, which, more often than not, is not located in the municipality where the actual production takes place. We correct for this bias and make sure that exports are attributed to the municipality that actually produced the goods by merging the export data with information from the Central Register of Enterprises of Brazil's Statistical Office (IBGE).

Determining transport costs is difficult given the lack of data on domestic freight rates across products along the municipality-customs export routes. In order to overcome these limitations, we follow Castro (2002) and

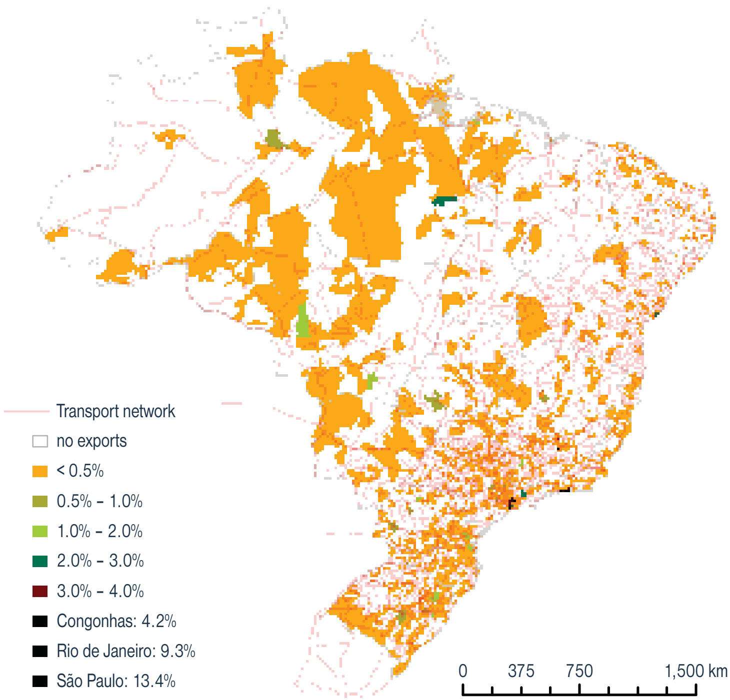
Combes and Lafourcade (2005) by using georeferenced data on operating expenses of cargo vehicles throughout the entire multimodal network. The source of the data is Brazil's National Logistic and Transport Plan (NLTP). With the help of geographical information system software, we use these data to identify the least costly municipality-customs export routes, whose transport costs are used as a proxy of the expenses effectively incurred. The combined exports-transport-costs database, at the product (6-digit Harmonized System)-municipality-custom level, covers 2007–2010. Details of its construction are found in the Technical Appendix.

Browsing the Data

Figures 6 to 8 present the main facts revealed by the data. The use of a finer geographical unit in Figure 6 reveals that levels of spatial concentration of Brazil's exports are much higher than data at the state or regional levels would indicate. Of the country's 5,563 municipalities, only 23 percent (1,284) exported in 2007–2010. The top 10 exporters accounted for as much as 46 percent of total exports while representing just 0.2 percent of the country's territory. Seven of those municipalities are in the Southeast where, as mentioned earlier, the bulk of the transport network is concentrated. Figure 7 shows that the municipalities with the most diversified exports are also in the Southeast; São Paulo, with 3,611 export products, ranks at the top, while the average is 57 products. Most of the municipalities in the less developed regions produce between 1 to 50 export products; those in the Center-West average 24, the North, 16, and the Northeast, 20 products.

Figure 8 shows that these highly unequal outcomes correlate with large variations in domestic transport costs for exports measured as the percentage of the export price. These costs reflect the municipalities' varying distances to customs, transportation modes, the quality of the infrastructure along the export route, and the type of product being exported (value, size, and weight, as described in the Technical Appendix). As can be seen, transport costs in the municipalities in the Center-West, North, and to a lesser extent, Northeast—the regions with the least export activities—are well above the country's average due to a combination

FIGURE 6 ■ Municipal Share of Exports and Transport Network. 2007–2010 (%)



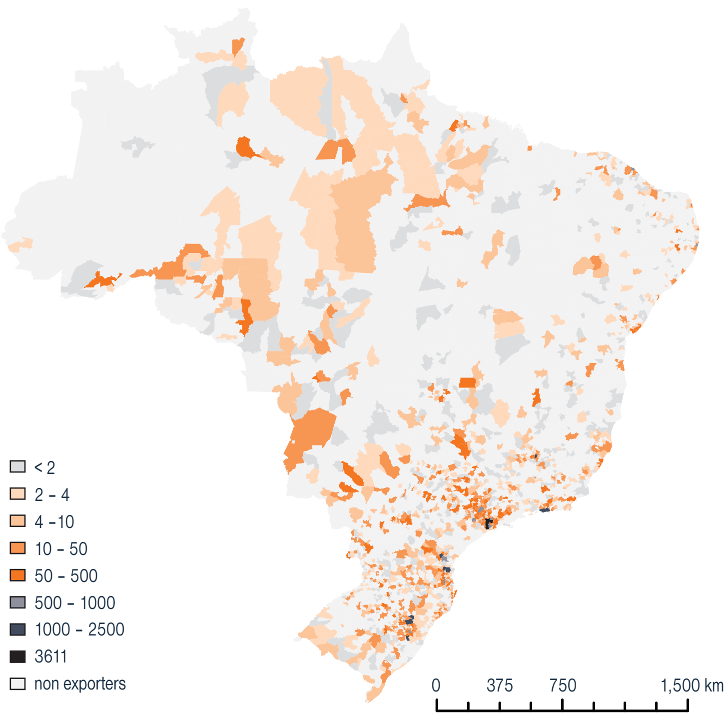
Source: Author's calculation based on primary data from Secretaria da Receita Federal. See Technical Appendix A.

of high weight to value natural resource exports, long distances to customs, and poor and limited transport infrastructure.[14]

All these facts beg the question of how much of this disparity of export outcomes can be explained by differences in domestic transport costs. The figures just described suggest that the role played by these costs is likely to be significant, but this evidence might be the product of "spurious correlations." The municipalities' ability to export is also determined

[14] The country's municipal average is 4.3 percent, with the North presenting the highest average (9.8 percent), followed by the Center-West (8.1 percent), the Northeast (6.2 percent), the Southeast (3.6 percent) and the South (2.4 percent). Note that these cover only transport costs, which, according to one estimate for the Brazilian case, account for only an average of 40 percent of all logistics costs, which also includes warehousing, port/airport fees, tolls, and other administrative expenses (Resende et al. 2012).

FIGURE 7 ■ Number of Products Exported by Municipality. 2007–2010



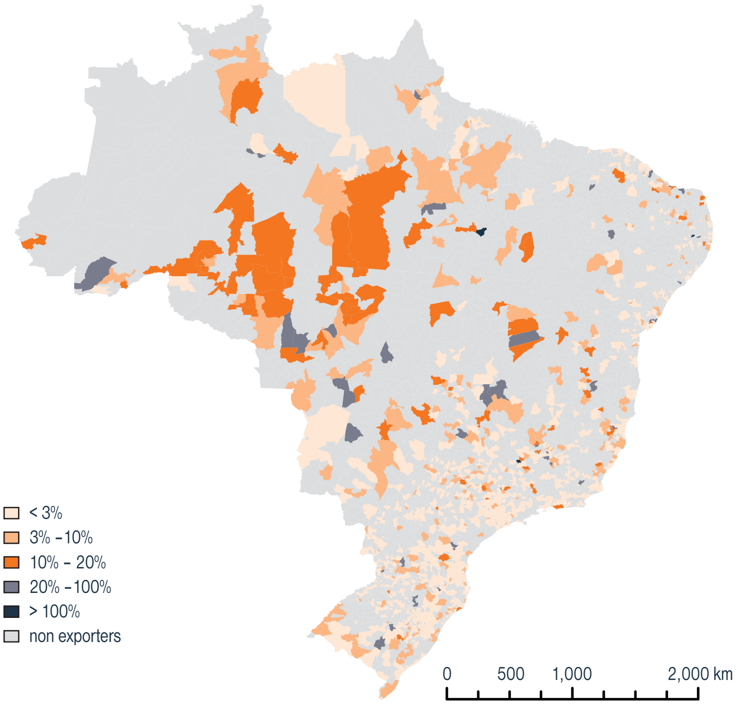
Source: Author's calculation based on primary data from Secretaria da Receita Federal. See Technical Appendix A.
Note: products correspond to the 6-digit Harmonized System.

by a multitude of other factors, including comparative advantages, government intervention, and historical accidents.

Estimating the Impact

We ran an econometric exercise to better understand the importance of these costs. In the exercise we attempted to estimate the impact of the costs on both the level and diversification of exports after controlling for the influence of other possible determinants. We sought to estimate an equation that relates municipal exports at the product level with their ad valorem transport costs to the customs of exit, and with permanent characteristics of the municipalities (comparative advantage and

FIGURE 8 ■ Average Municipal Ad Valorem Transport Costs to Export 2007–2010 (%)

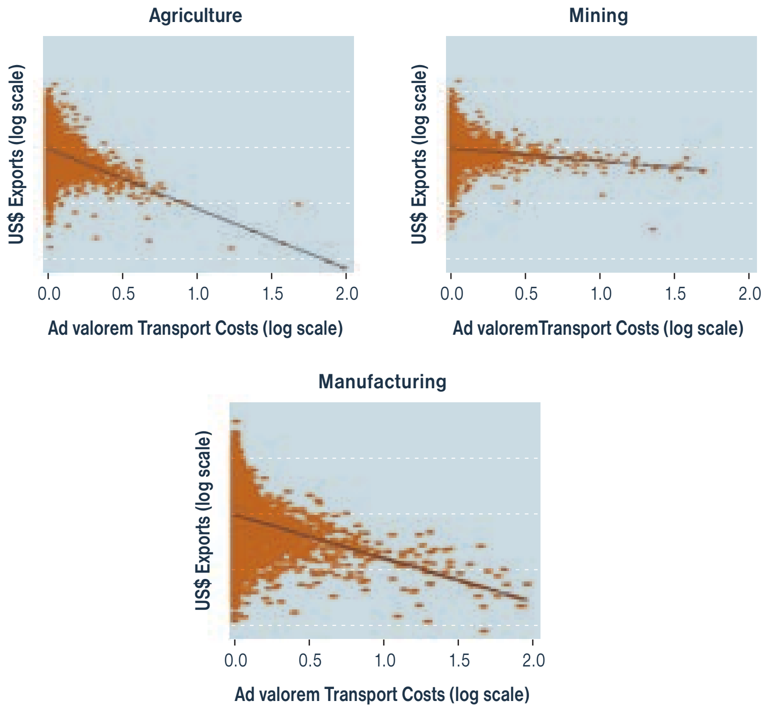


Source: Author's calculation based on primary data from the PNLT. See Technical Appedix A.

institutions), products (dimension and transportability, and customs (port specialization) that might also affect exports. The equation also takes into account year-specific events that could bias the results. Since the impacts are likely to vary significantly across types of products due to differences in transportability (Hummels 2001), we estimated different equations for manufacturing, agriculture, and mining, pooling data over 2007–2010.

The results, which are contained in Figure 9 and discussed in more detail in the Technical Appendix, confirm the inverse correlation of transport costs with level of exports. In fact, their impact is substantial: a 1 percent reduction in ad valorem transport costs increases exports by as much as 5 percent in agriculture, 4 percent in manufacturing, and 1 percent in mining.

FIGURE 9 ■ The Impact of Transport Costs on Exports by Sector



Source: Author's calculations.
Note: Graphs based on the results of an OLS regression model with municipality-customs-product and year fixed effects. See appendix for details.

Though revealing, these figures should be regarded as rough estimates for at least three reasons. First, as noted earlier, they do not capture indirect effects of transport costs on production. Estimates of such effects are hard to find in the literature, but Atack, Haynes, and Margo (2010), for instance, suggest that lower costs of rail transport in the second half of the 19th century accounted for as much as a third of the increase in the number of manufacturing establishments in the US regions that benefited from those investments.

Second, the figures miss the impact of transport costs on municipalities that do not export, because we cannot observe their products or their customs of exit. This is particularly worrisome because those are likely the very municipalities with the highest transport costs. The importance of this bias, though, is seen as directly correlated with the impact of transport costs on the probability to export, and our estimates in this regard suggest a very small impact.[15] The third reason for concern is the issue of reverse causality mentioned earlier. Higher levels of exports are likely to lower transport costs because of economies of scale and their effect in encouraging investments to improve infrastructure.[16] If these effects are sufficiently strong, our estimates would be overstating the impact of transport costs on exports. To assess the extent of this potential bias, we replace transport costs by another variable that is correlated with it, but that is not affected by the level of exports, such as the straight line distance to the customs of exit. Our results suggest that we are more likely to be underestimating than overestimating the role of transport costs in export levels.[17]

In addition, we test the possibility that transport costs might affect not just how much of each product each municipality exports, but also the number of products exported. The empirical strategy is very similar to that used above, except that in this case: (a) the dependent variable is the number of products exported by each municipality and; (b) we drop the customs dimension of the data, i.e., we focus on the performance of the municipality as a whole and not on the number of products exported through each customs office.

As expected, transport costs are found to have a negative and statistically significant impact, but the magnitude of this impact varies significantly: a 10 percent drop in transport costs would increase the number of products exported between 4 to 7 percent. These results depend not so much on the sector, but on the measures used to estimate the municipalities' overall shipping costs.

Figure 10 illustrates this point, presenting estimates for different ways of measuring transport costs in each of the sectors. We see little variation across sectors, although manufacturing is affected slightly more

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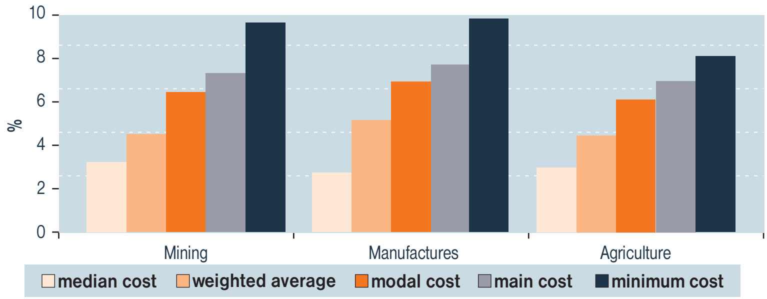
[15] See Helpman, Melitz, and Rubenstein (2008). See Technical Appendix C for details of the estimation and results.

[16] See Kleinert and Spies (2011).

[17] See Technical Appendix B.

FIGURE 10 ■ The Impact of a 10% Drop in Transport Costs on the Number of Products Exported by Municipalities
Selected summary measures, 2007–2010



Source: Author's calculations.
Note: Estimates based on results of a Poisson regression model with states and year fixed effects. See Technical Appendix D for details. The definitions of transport costs measures are:
(a) weighted average: the municipality's average shipping cost to the used customs offices, weighted by the value of exports;
(b) modal: shipping costs to the most frequently used customs office;
(c) minimum: least costly option among customs offices;
(d) median: the median costs to ship to all customs office options;
(e) main: the shipping costs to the most used customs office defined by the value of exports.

by transport costs than mining and agriculture, which would be expected given its higher potential for product diversification. The variation arises from the different proxy measures used—once you drop the customs dimension you are left with the largely arbitrary decision on how to best represent the municipality's transport costs.[18] Overall, even if we consider the upper bound of these estimates, the impact seems to be significantly lower than that on the value of exports, as discussed earlier.

What Does that Mean for Public Policies?

Moving this discussion closer to the policy arena, we use these estimates and our georeferenced database on exports-transport costs to take a first look at the likely impact on exports of improvements in the qual-

[18] The fact that exports from a given municipality are typically concentrated in a few customs offices discourages the use of simple averages. But that is as far as one can go in defining criteria to select one of these measures.

ity and extension of the country's transport network. We focus on two improvements:[19]

- Upgrading all roads with top quality pavement, as defined by the Ministry of Transportation. In our 2007 benchmark year, 26 percent of roads had pavement rated good, 54 percent regular, 16 percent bad, and 4 percent precarious.
- Expanding the multimodal network to include all railway and waterways projects in Brazil's National Logistic and Transport Plan (NLTP), whose main objective is to connect the remote agricultural and mining regions in the North, Central-West, and Northeast, to the country's ports.[20] The railway projects that account for the bulk of the planned expansion are the North-South, East-West, New Trans-Northeast, and the transcontinental railway. Waterways projects that stand out are the Tocantins and the Tele Pires-Tapajos waterways in the North and Central-West (see Figure 11).

Although stylized, this scenario is very much in line with NLTP's objectives, where railways, and to a lesser extent, waterways, account for nearly all the projected extensions of the multimodal network. Road investments are mostly limited to improvements in quality and capacity. Incorporated into our dataset, these improvements would translate into an average cut in transport costs of 12 percent for each route used for exports in 2007–2010. The estimated impact of these improvements on municipal exports is presented in Figure 12. Despite the methodological limitations mentioned earlier, the results provide a powerful illustration of the role of domestic transport costs as an explanation for Brazil's spatial

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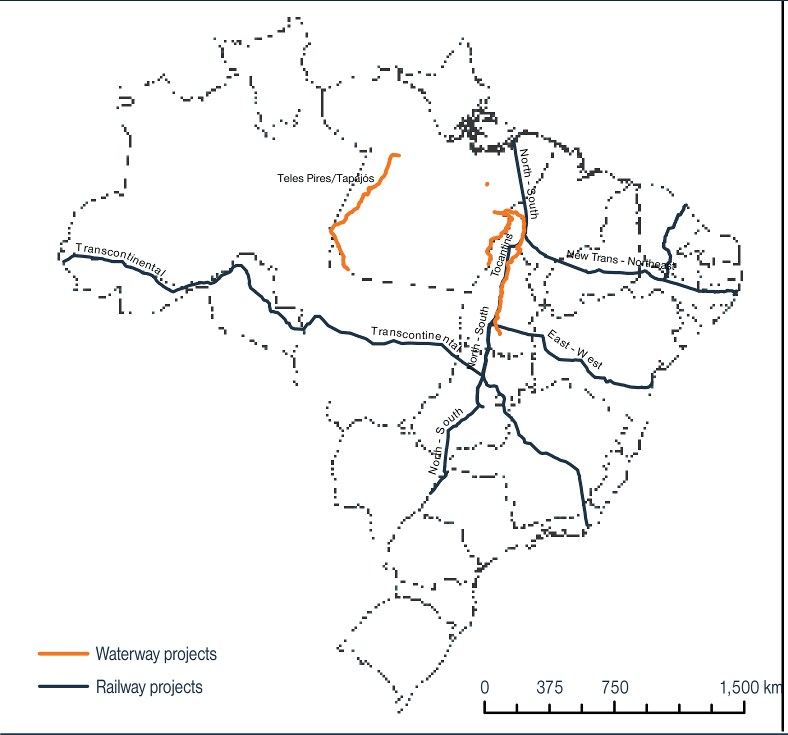
[19] See Technical Appendix E for details of the exercise.

[20] The NLTP, first introduced in 2007 and revised in 2009 and 2011, is a tool used to support the planning of public and private investments in transport infrastructure. It has produced a georeferenced database of Brazil's transport network and a portfolio of transport projects initially covering 2007–2023 and recently extended to 2031. The 2011 revision contained investments of RS$423 billion distributed among 1167 projects. See PNLT 2009 and 2012.

FIGURE 11 ■ Brazil's National Logistics and Transportation Plan

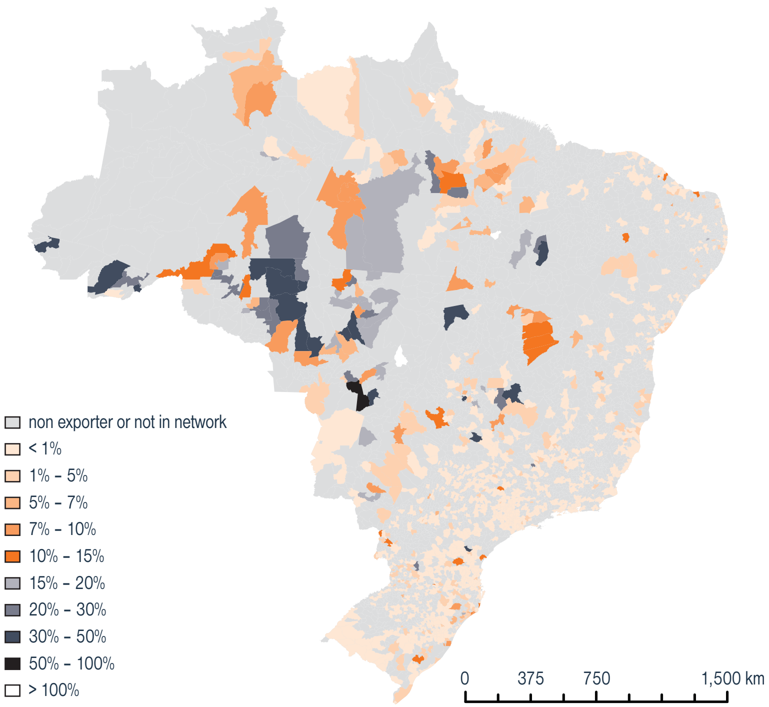


Source: Author's calculations based on PNLT 2007 data.

export disparities. It is immediately evident that most of the significant gains from the improvements are concentrated in municipalities in the North and Central-West, where exports would increase 13 percent and 12 percent, respectively. The Northeast, the South, and the Southeast show considerably lower impacts, with exports increasing 2 percent, 1 percent, and 0.5 percent, respectively.

Much of these results would be expected since the most significant transport projects in the simulation involve the less developed regions. Yet, even if investments were evenly distributed across the country, regions such as the North and the Central-West would benefit disproportionately simply because: (a) that is where the infrastructure is the most precarious or absent, and (b) these regions are mainly producers of "heavy" commodities, located far from the main ports and as such,

FIGURE 12 ■ The Impact on Exports of Selected Improvements in Brazil's Multimodal Network

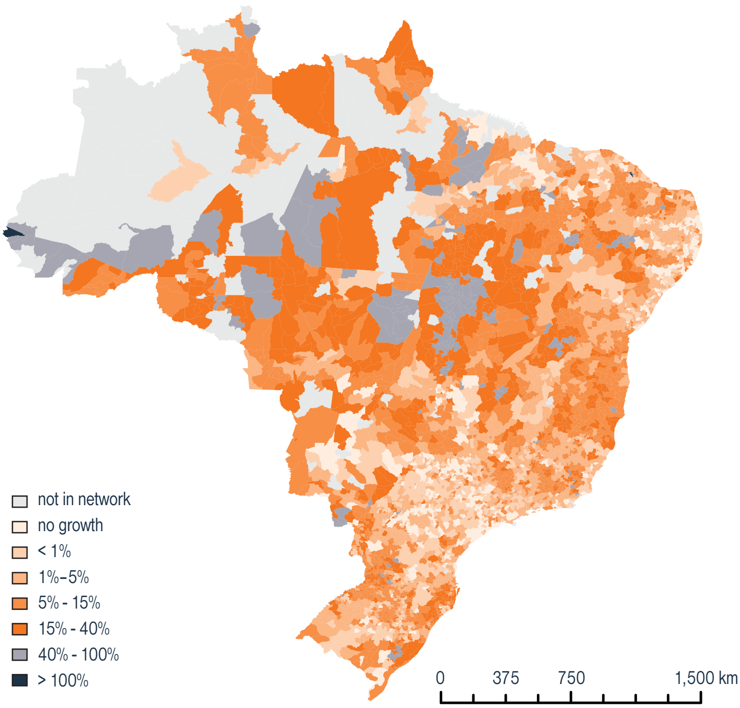


Source: Author's calculations.
Note: Predictions from an OLS model with origin-destination-product and year fixed effects. This case shows the average impact using 2007–2010 data. See Technical Appendix E.

would most likely benefit from railway and waterways. The Northeast shares some of these characteristics, but not all. The coastal proximity and the incipient production of agriculture commodities dampen the immediate benefits.

In the case of the Southeast, transport improvements would produce their greatest benefits by reducing traffic congestion, a factor that is not included in our simulation. Although pavement improvements affect shipment times and, therefore, transportation costs (see the Technical Appendix), our stylized network by no means captures the impact of the severe congestion that affects most of the Southeast network, particularly access to the ports.

FIGURE 13 ■ The Impact of Selected Improvements in Brazil's Multimodal Network on the Number of Products Exported (%)



Source: Author's calculations based on information from SRF, CEMPRE (IBGE), Produção Agricola Municipal (IBGE), Brazil's Central Bank and PNL.
Note: Predictions from a Poisson model with state and year fixed effects. Minimum cost to customs. See Technical Appendix E.

We also assess the impact of these investments in terms of the number of products exported by each municipality, assuming that they all travel over their minimum cost route. As shown in Figure 13, the low density of the transport infrastructure, long distances from the coast, and specialization in a small number of primary products result in the most significant gains for the North and Central-West. The municipalities in these regions, which presently export on average three to four products, would see these numbers increase by an average of 23 percent and 13 percent, respectively. In the Northeast, where the level of diversification is comparable to that of other less developed regions (two export

Box 1: How Reliable Is Our Data? A Case Study of Soy Exports

Our empirical analysis of the role of transport costs in Brazil's export disparities relies on information of operational expenses rather than data on domestic freight costs. Soy exports are one of the few exceptions where data on domestic freight costs is available, and thus offers a valuable opportunity to test the robustness of our findings. Even though soy exports represented just 11 out of the approximately 7,300 products exported annually in 2007–2010, it accounted for 9 percent of Brazil's exports in the period. In addition, soy exports were arguably the main driver behind the rise of the Central-West, which was the only significant example of spatial deconcentration in Brazil since the onset of industrialization.

The relevance of freight costs of soy exports is also underscored by their "transport-intensity"; our data show that the ad valorem transport cost of soy exports is twice as much that of an average good. An additional feature of soy exports is their heavy concentration in a few municipalities, with the top ten exporters accounting for 74 percent of all exports. Municipalities where soy production is located are in three distinct regions—South, Central-West, and Northeast—and distances to port vary from 290 to 1500 miles. This variety of factors facilitates the identification of the role of transportation costs.

We added freight costs to our analysis with assistance from ESALQ-LOG, a research group on agriculture logistics at the College of Agriculture of the University of São Paulo (ESALQ-USP) led by José Vicente Caixeta and Priscila Biancareli Nunes.[1] This collaboration allowed us to merge our georeferenced database on exports-transport-costs with SIFRECA, ESALQ-LOG's freight database, which covers mostly road transportation of agricultural products. Through our collaboration, we could associate a road freight cost to each of the road-based routes for soy exports (municipality-customs), as well as validate the practical relevance of these routes (see Technical Appendix F for details).

This exercise produced a number of important results. First, our operational measures of transport costs are highly correlated with freight costs, with a coefficient of correlation of 0.97, and are, on average and as expected, lower than these costs. The average markup of freight over operational cost is 4 percent. The Central West municipalities have the highest ad valorem operational and freight costs, reaching 15 percent and 18 percent, respectively, whereas the municipalities in the Southeast have the lowest, with these same costs averaging 3 percent and 5 percent, respectively.

In addition, we estimated the impact of transport costs on soy exports with the same empirical strategy adopted earlier for all exports, using both operational and freight measures. The results point to a significantly higher impact than that estimated for agricultural goods as a whole and consistency across the two transport costs measures. According to these estimates, a 1 percent drop in transport costs would increase soy exports by as much as 20 percent, in the case of operational expenses, and by 16 percent in the case of freight costs (see Technical Appendix F for details).

Apart from incorporating freight costs, we also added another dimension to the analysis by looking at the impact of transport costs on producer prices. This was done with the use of another ESALQ-USP survey conducted by the Center for Advanced Studies on Applied Economics (CEPEA), which collects daily spot prices for soybeans in municipal markets. We linked this price information with our exports-transport-costs georeferenced database.

[1] Respectively, ESALQ director and coordinator of ESALQ log.

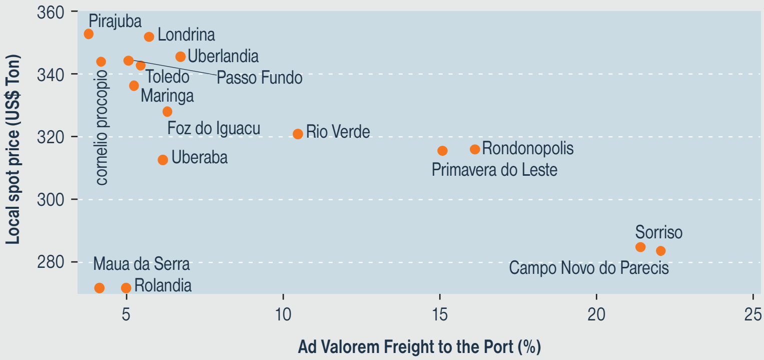
Continued on next page

Box 1: *(continued)*

Figure B1 shows that, with few exceptions, producers in municipalities with the highest domestic freight costs are paid the lowest prices, and that the price difference between high (e.g., Sorriso in the Central-West) and low cost municipalities (e.g., Londrina in the South) can be as high as 25 percent.

To ensure that this inverse relationship is not a result of some spurious correlation related to non-observable characteristics of municipalities and ports, we regressed prices on ad valorem freight costs controlling for these characteristics. The results tend to confirm the negative relationship between producer ("farmgate") prices and freight costs, though pointing to a moderate impact. For instance, a 10 percent drop in freight costs would increase prices by 1.2 percent (see Technical Appendix F). Further research is clearly warranted, but considering the much higher estimates for the impact on the value of exports, it appears that transport costs have a more negative impact on the volume than on the local prices of these exports.

FIGURE B1 ■ Producer Prices for Soybeans and Transport Costs
2007–2010 average



Source: Own calculation based on ESALQ-CEPEA and ESALQ-SIFRECA. See text and Technical Appendix for details.

products on average), would experience a more limited 7 percent gain, since, as noted above, the proximity of the coast is likely to reduce the relative impact of the investments. The significantly more diversified South and Southeast would see average increases of 8 percent and 5 percent, respectively.[21]

[21] The magnitude of the gains varies significantly depending on the proxy used for the municipality's transport costs, as discussed in the previous section and illustrated by Figure 10. The spatial distribution of the impact, though, barely changes.

Why So Slow?

The message that emerges from the empirical evidence reviewed in this chapter is clear: by improving its transport infrastructure Brazil can not only boost the volume and diversification of its exports, but also spread the benefits of trade more evenly across its regions. This double benefit cannot be overlooked by a country that has yet to achieve a share of the world market consistent with its size and that faces acute regional disparities. The burning question, then, is why Brazil is not closing its infrastructure gap more rapidly? Why is it not harvesting this low-hanging fruit?

A brief look at Brazil's recent investment plans show that this slow response is not due to lack of a proper diagnosis. The NLTP, whose data and projects were used in our simulations, clearly sets forth the main shortcomings of Brazil's transport network discussed earlier: the regional asymmetries, the inadequacy of the mode composition, and the generally poor conditions of the existing network. The NLTP also presents a portfolio of projects that match the priorities of most analysts and business associations.[22]

Despite the accuracy of the diagnosis, the symptoms of under-investment seem to persist. To be sure, as mentioned earlier, investments in transport infrastructure have increased significantly since the early 2000s, more than trebling between 2002 and 2010, according to one estimate (Campos Neto and de Moura 2012). However, they still fall well short of the country's needs.

For one thing, transport investments are estimated to remain below 1 percent of GDP. This is well below the 2 percent peak of the 1970s, which was not sufficient to give the country a world-class transport network.[23] For another, investments have been falling well short of targets set by the government's own plans. For instance, only 34 percent of the NLTP's US$208 billion portfolio of investments (approximately 8 percent

[22] See, for instance, IPEA (2010), CNT (2011), and CNI (2012).

[23] The Campos Neto and de Moura (2012) estimate for 2010 was 0.7 percent of GDP. It is unlikely that these figures have improved recently since direct public spending in transportation (i.e., excluding financing from state banks such as BNDES), which is one of the key components of the overall investment in the area, fell in 2011. It is also believed that direct public spending performed poorly in 2012 due to institutional issues.

of GDP) was included in the Program to Accelerate Growth (Programa de Aceleração de Crescimento-PAC), launched in 2007, whose projects have government funding assured. But even those projects have been facing significant delays in their execution. As of 2011—three years before the program officially ends—only 8 percent of the transportation projects had been concluded.[24] The level of investment in transport infrastructure also looks modest when compared to those of other emerging countries, notably China, which, according to one estimate, invested an annual average of 4.5 percent of its GDP in the sector between 1992 and 2011.[25]

If it seems clear that low investment is a key piece of the puzzle, why has it been so low? The usual suspects are fiscal constraints, all too common in developing countries. Yet in Brazil, the explanation seems to go beyond these constraints to choices that have been made on priorities and execution.

As regards priorities, even a cursory analysis of the country's budgetary decisions in the last decades reveal that substantial progress could have been made if the massive resources invested on low return and risky initiatives were shifted towards the low risk and high social gains of transport investments. The loans of Brazil's development bank, BNDES (National Bank for Economic and Social Development), are a case in point. The bank disbursed US$186 billion in concessional loans to manufacturing in 2003–2012, 70 percent of them to large firms with direct access to local and international capital markets. These loans nearly equaled the value of the entire NLTP portfolio.[26]

As for execution, institutional and regulatory weaknesses appear to have impaired the public sector's ability to select and execute transport projects and to leverage private sector contribution. The Ministry of Transportation emerged from the fiscal crisis of the 1980s and 1990s with a shortage of qualified employees; even after undergoing a number of reforms, it has yet to fully recover its policy formulation and planning capabilities. The two land and water transportation agencies, ANTT and ANTAQ, which were created in 2001 to regulate and supervise concessions and other forms of public

[24] See PNLT (2012) and *http://www.pac.gov.br/sobre-o-pac*.

[25] See McKinsey (2013), p.12.

[26] *http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/BNDES_Transparente*.

private partnerships (PPPs), are generally considered to be understaffed and vulnerable to political and special interest pressures.[27]

These institutional weaknesses have been compounded by a hesitation to tap the private sector's financial and managerial resources. While important advances have been made in roads and railways, their pace and scope have not been not consistent with either the urgency or the potential gains of bringing transport costs down. As of 2012, 15,473 km of roadways were under private concessions, which put Brazil behind only China in length of this type of concession (Verón and Cellier 2010). However, most of these actions were carried out at the state level, particularly in Sao Paulo, where the all-important interstate highways under federal administration represented just 31 percent of the concessions (less than 1 percent of the paved federal network).[28]

Better progress has been made with railways. Nearly the entire existing network was transferred to the private sector in the second half of the 1990s, which led to significant increases in investment and traffic (ANTT 2012). However, the concessions did not address pressing needs to expand the network (IPEA 2010b). In practice, this task has been left to the state company VALEC, whose problems of governance—not that much different from those of the RFFSA, the state company that disastrously managed the country's network until the late 1990s—has led to significant delays in the execution of the new projects.[29]

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[27] ANTT and ANTAQ were at the bottom of the federal ranking in Correa et al. evaluation in 2006 of Brazil's regulatory agencies. Verón and Cellier (2010, p. 38), in turn, looking at the ANTT case, state the following: "to further strengthen governance, the government could ensure that agency directors and managers are consistently selected on the basis of their technical and managerial qualifications, and are independent from political and private interests."

[28] Launched in 1995 with a round of 1482 km, the federal program would take more than 10 years to add a second round of 2600 km. The opportunity cost of these delays can be gauged by the stark contrast between the conditions of the private and state run roads: as of 2012, 86 percent of private-run roads were considered in excellent or good condition in contrast to only 28 percent of the state-run network (CNT 2012). For details of the concession program see ABCR *http://www.abcr.org.br/Conteudo/Secao/43/estatisticas.aspx* and ANTT *http://www.antt.gov.br/index.php/content/view/4978/Historico.html*.

[29] Created in 1989 to carry the construction of the North-South Railways, VALEC has the concession of the most significant expansion projects in the country discussed earlier: the North-South, East-West, and Transcontinental railways. See IPEA (2010b) and *http://www.valec.gov.br/index.php*.

Among other modes of transport, cabotage would be an important low-cost option in a country with 7,408 km of coastline. However, misplaced nationalism seems to be hampering its development. Competition in maritime transport services has been limited by measures such as the prohibitive import tariffs on foreign ships that significantly raise the costs of operators. As the result of these measures, in addition to Brazil's well-known problems of port congestion, cabotage's share of domestic freight flows remains well below 1 percent.[30]

This survey barely scratches the surface of the breadth and complexity of policy and institutional challenges that hamper transport in Brazil. But despite the obvious problems, there are good reasons to be optimistic about the future. In August 2012 the government announced a package of investments totaling approximately US$66 billion over the next 25 years (57 percent of which will be made over the next five years) to duplicate 7,500 km of roadways and build 10,000 km of new railways, which would represent a 35 percent increase over the existing network. More important than the sums involved is the decision to carry out most of these investments under concessions and public-private partnerships and at the same time attempt to address regulatory issues that have increased costs and restricted competition in the previous rounds of concessions.[31]

The announcement of the investment package was followed by measures to increase private sector participation in the management and expansion of ports and airports by overhauling an institutional and regulatory framework that has hindered investments in those sectors for decades.[32]

Even though the details have yet to be defined and some of the country's major opportunities in waterways and cabotage were not

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[30] ANTAQ (2012). See a more detailed discussion of the problems facing cabotage in Brazil see Dias (2009).

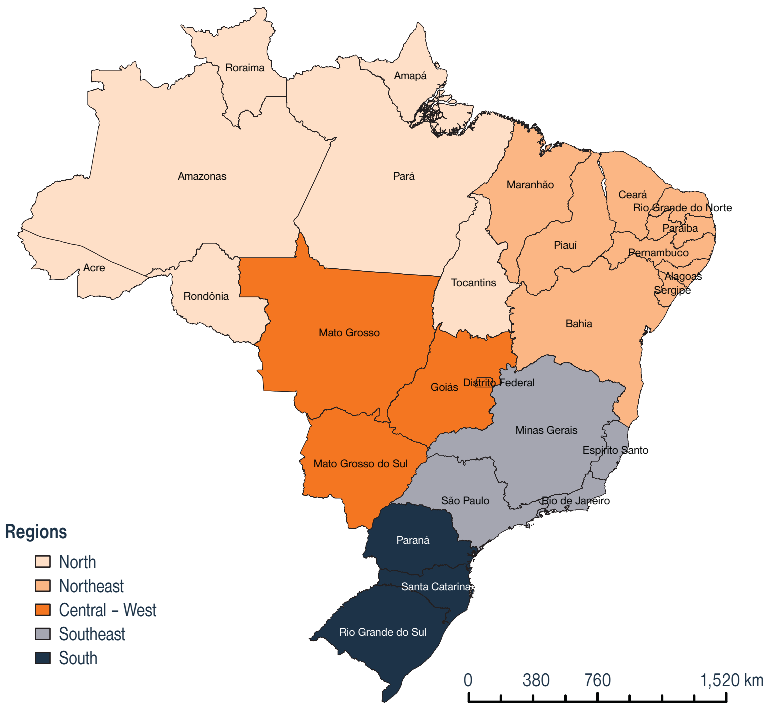
[31] See *http://www.transportes.gov.br/public/arquivo/arq1345056805.pdf.*

[32] The proposed measures for ports can be seen at *http://www.planalto.gov.br/ccivil_03/_Ato2011–2014/2012/Mpv/595.htm*. The measures for the airports are summarized in *http://www.aviacaocivil.gov.br/noticias/2012/12/governo-anuncia-programa-de-investimento-em-aeroportos*.

addressed, these initiatives clearly signal a break with the inertia of the past, raising hopes that the country is finally on track to rectify centuries of transport infrastructure neglect.

Technical Appendix

FIGURE A.1 ■ Brazil's States and Regions



Source: Author's calculations based on IBGE data.

Appendix A – The Exports-Transport-Costs Database

In building this database we faced two challenges: establishing the origin (municipality) of the exports, and determining their transport costs to the customs of exit. We will look at each of these in turn.

Establishing the origin of exports. Our original export dataset comes from Brazil's Internal Revenue Service (SRF) and contains information at the eight-digit-level of *MERCOSUR Common Nomenclature (NCM)*, on the date (month and year, from January 2007 to December 2010), value (US$), weight (kg), the state and municipality where the customs declaration was filed, the reported state of production, and the customs used for each transaction.

The municipal data in this dataset is comprehensive, but it is biased towards the largest cities because firms tend to use their headquarters to file information about their exports. More often than not, these headquarters are not located in the municipality where the actual production took place.

We corrected for this bias by merging the original export dataset with the 2008 data from the Central Register of Enterprises of Brazil's Statistical Office (CEMPRE-IBGE) using a IBGE concordance between the NCM and the National Classification of Economic Activities (CNAE). The CEMPRE has information on the municipalities' economic activities (four digits CNAE), number of firms, employment, and wages. In the case of agriculture, we also used an IBGE database on municipal agriculture production (Produção Agricola Municipal) whenever CEMPRE information was not sufficiently detailed.

Using this combined database, we applied an algorithm to adjust the SRF municipal export data. The algorithm followed two basic principles: (i) the SRF data remained unchanged whenever the municipality where information was filed was in the state reported as the state of production, and the municipality used in the filing appeared in CEMPRE as having produced the good in question; and (ii) whenever a mismatch between the state of the municipality and the reported state of production was observed we reassigned the export to a municipality in the same state of production that exported the same product through the same customs of exit found among the observations consistent with (i) or CEMPRE, if no match was available. When more than one match was found, we used a tiebreaker based sequentially on the municipality with the highest payroll, employment, number of establishments, and exports of the product in question. Approximately 45 percent of the observations remained unchanged (i.e., consistent with the first principle). A detailed description of the algorithm is available on request.

Calculating transport costs. In calculating the transport costs along the municipality-customs export routes, we followed Castro (2002) and Combes and Lafourcade (2005) and used georeferenced data on operating expenses of cargo vehicles across Brazil's multimodal network. The source of the data is Brazil's National Logistic and Transport Plan (NLTP), which was first published in 2007 and later revised in 2009 and 2011.

Georeferencing the data. The first step was to assign geographic locations to our sample of export municipalities and exit customs using NLTP maps of the multimodal network. The capitals of the municipalities were used as the origin, and the customs were assigned to the locations of the corresponding ports, dry ports, and airports.

Most municipalities and exit customs did not have an exact location in the network because it does not include all existing roads, particularly local roads. In order to avoid data loss, we set a tolerance allocation threshold of 40 km to the network. In other words, exports that originated at, or were going to, points located further than 40 km from the network were excluded from the sample, while all origin-destination pairs located within that threshold were assigned to the closest point in the network.

The threshold chosen, which seems somewhat arbitrary, was mainly determined by a trade-off between choosing a distance that could potentially be attributed to local roads and the impact on our sample, i.e., its product, and regional coverage. Several different thresholds were tested that resulted in different samples, but the econometrics results, discussed in detail below, did not change significantly. The 40 km threshold excluded 194 of Brazil's 5,563 municipalities, 16 of which were exporters in our sample.

Determining costs. The second step involved calculating the operating costs for each part of the multimodal network, which was done as follows:

For roads: The NLTP operating expenses data include six cost variables (depreciation of vehicle and tires, fuel, lubricants, maintenance, wages, and overhead) that cover three dimensions of road quality and three types of trucks. The dimensions of road quality include: type (paved and not paved, single, and two-lanes), relief (mountainous, undulating, or flat) and pavement (very poor, poor, regular, and good). These dimensions are associated with three types of trucks with different cargo capacities (two axle, three axle and articulated trucks) to form an operating cost matrix.[33]

This operating cost matrix was then applied to approximately 22,000 road sections (so called "links"), following Combes and Lafourcade (2005) distance and time cost formulation.[34]

Transport costs = Distance costs + Time costs

$$\textit{Distance costs} = \frac{(\textit{fuel} + \textit{lubricant} + \textit{tires} + \textit{spare parts}) * \textit{length of link}}{1000 * \textit{truck capacity in tons}}$$

$$\textit{Time costs} = \frac{(\textit{maintenance} + \textit{capital} + \textit{crew}) * \textit{length of link}}{1000 * \textit{truck capacity in tons}}$$

The resulting variables are then expressed in *reais* per ton for each vehicle. Note that no proxy of speed was included in our time costs, because this factor is already implicit in our maintenance, capital, and crew variables.

For waterways: The costs per ton and km reported in the PNLT 2010 were used.

For railways: The costs per ton and km reported in the PNLT 2010 were used.

As mentioned before, since the network did not include all the local roads, in some cases we had to assume the existence of roads connecting the railway stations/ports/terminals to the road network. These stretches were assumed to be the same road type as regards to pavement, relief, etc., as the nearest road to which they were linked. In order to check for

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[33] See PNLT 2007, volume 3, tome 3.

[34] Our original costs data are expressed in costs incurred per 1000 km traveled, hence the adjustment in the denominator. Total costs were calculated for three types of vehicle with different capacities, but estimation results correspond to Vehicle 5 (capacity: 13.2 tons).

robustness and consider the potential effect of these links on our estimations, this procedure was done in two different ways: a) all stations/ports/terminals were linked to the closest road, no matter how far this road was; b) only links shorter than five km were considered. The results were not significantly altered by this procedure, and option (a) was generally used, because it produced more realistic routes.

Since we only had the 2006 road operating cost matrix available, we used cost-specific price indices (the components of IBGE-IPCA for materials, IBGE-PME for labor earnings, and the FIPE vehicle price survey for depreciation) to build a time series compatible with our 2007–2010 export data. The implicit assumption here is that there were no significant technological/productivity changes during the period. For the operating costs of waterways and railways the general IBGE-IPCA was used to deflate the series.

With the origins and destinations inserted into the network, and with the operating costs of each section/mode available, we used the ArcGis software to find the optimal or minimum cost route for each municipality-customs pair in the period of the analysis. The optimal costs of these routes were then converted to US$ using the average annual exchange rate reported by Brazil's Central Bank, and divided by the US$ value of each product-municipality-custom annual exports to produce estimates of their ad valorem transport costs. More specifically:

$$ad\_val\_cost_{m,c,p,y} = TC_{m,c,p,y} \cdot \frac{W_{m,c,p,y}}{X_{m,c,p,y}}$$

where $ad\_val\_cost_{m,c,p,y}$ is the ad valorem transport costs of good p that is transported from the municipality m to customs c in year y; $TC_{m,c,p,y}$ is the transport costs of shipping 1 ton of generic merchandise from municipality to customs c in year y, $W_{m,c,p,y}$ is the weight (expressed in tons) of good p, and $X_{m,c,p,y}$ is its export value.

As a robustness check for the regression exercise, we also calculated different sets of operating and valued added costs based on a road-only network and on alternative estimates for the operating costs of railways and waterways drawn from Barbosa (2008).

Appendix B – Estimating the Impact of Domestic Transport Costs on the Value of Exports

Our empirical strategy is based on the following OLS baseline specification inspired by Hummels (2001):

$$ln(export_{m,c,p,y}) = \alpha_j + \beta_j . ln(1 + ad\_val\_cost_{m,c,p,y}) + fx_{m,c,p,} + fx_y + \varepsilon_{m,c,p,y}, \text{ with } p \in j \quad \text{(b.1)}$$

Where $export_{m,c,p,y}$ is the exports of the municipality m to customs c of good p (6-digit HS) of category j (agriculture, mining, manufactures, and other goods) in the year y. *ad_val_cost* is the ad valorem transport costs (see definition and data sources in Appendix A) of shipping good p from municipality m to customs c in year y, α_j is a constant, $fx_{m,c,p,}$ is a municipality-customs-good fixed effect, fx_y is a year fixed effect and $\varepsilon_{m,c,p,y}$ is the error term. β_j is our variable of interest. The equation is estimated separately for three groups of goods: agriculture, mining, and manufacturing. The product groups are defined according to the WTO classification, which in turn defines goods according to Revision 3 of the Standard International Trade Classification (SITC). Table B.1 presents the results of the estimations.

For robustness, we ran an alternative specification without the customs dimension, taking the lowest ad valorem cost observable for each municipality-good pair in each year. The results did not change significantly for the main product categories.

Table B.1 ■ The Impact of Domestic Transport Costs on the Value of Exports: Pooled OLS, 2007–2010.

	Agriculture	Mining	Manufactures	Others
ln(1+ad val cost)	−5.412***	−1.144***	−3.933***	7.874
	(1.041)	(0.420)	(0.420)	(941.300)
R-squared	0.0107	0.0166	0.0138	0.552
Observations	43,325	10,418	462,755	360

Note: *** p<0.01, ** p<0.05, * p<0.1 Robust standard errors in parentheses.

Table B.2 ■ The Impact of Domestic Transport Costs on the Value of Exports: Pooled OLS 2007–2010 with GC Costs

Original Sample	Agriculture	Manufactures	Mining	Others
ln(1+ ad valorem costs)	-5.171***	-3.874***	-1.142***	58.149
	(1.156)	(0.412)	(0.414)	(593.252)
R-sq	0.01	0.01	0.02	0.60
Observations	41,453	438,030	9,866	338
Historic Sample	**Agriculture**	**Manufactures**	**Mining**	**Others**
ln(1+ ad valorem costs)	-3.276**	-4.343***	-6.546***	-2,543.409
	(1.367)	(0.556)	(1.318)	(6,902.838)
R-sq	0.007	0.02	0.05	0.8
Observations	10,570	87,908	2,743	97

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

To address reverse causality concerns between exports and transport costs, we used, as in Banerjee et al. (2004), the great circle (GC) distance ("straight-line" to customs) as an alternative variable for ad valorem transport costs in OLS and instrumental variable exercises.

First, we recalculated the ad valorem operational costs, replacing the actual one for GC distances, and used these new costs to run the baseline regression (b.1). Since export locations might also be affected by transport costs, we also ran this same regression limiting the sample to historic municipalities (excluding those not registered in the population records between 1907 and 1912) and ports (founded before the 20th century).The results for the main categories, presented in Table B.2, were mostly on the same order of magnitude as those obtained on our baseline specification. The exception is the coefficient for mining in the historic sample regression, which is considerably higher.

Second, we used the GC distances as an instrument for ad valorem costs in a two-stage regression, as follows:

1st stage:

$$ln(1+ad\_val\_cost_{m,c,p,y}) = \gamma + \gamma_j \cdot ln(great\_circle\_distance_{m,c}) \quad \text{(b.2)}$$
$$+ fx_{m,y} + fx_{c,y} + fx_{p,y} + \mu_{m,c,p,y}, \text{ with } p \in j$$

2nd stage:

$$ln(exports_{m,c,p,y}) = \alpha + \beta_j \cdot ln(1 + \widehat{ad\_val\_cost}_{m,c,p,y}) + fx_{m,y} + fx_{c,y} + fx_{p,y} + \varepsilon_{m,c,p,y}\text{, with } p \in j \quad \text{(b.3)}$$

Note that the fixed effects used—municipality-year $fx_{m,y}$, customs-year $fx_{c,y}$ and product-year $fx_{p,y}$—are different from the ones used in the baseline regression. This had to be the case since a municipality-product-customs fixed effect would be collinear with the great circle distance, which does not vary in time, but only in the origin-destination dimension. The results, with both the original and historic sample are presented in Table B.3. They suggest that the baseline specification is underestimating the impact of transport costs, but the coefficients are too high to be credible. Moreover, the fact that the IV and OLS

Table B.3 ■ The Impact of Domestic Transport Costs on the Value of Exports: IV specification, 2007–2010.

Whole Sample				
First stage	**Agriculture**	**Manufactures**	**Mining**	**Others**
ln(great circle distance)	0.008***	0.003***	0.012***	0.002**
	(0.000)	(0.000)	(0.001)	(0.002)
R square	0.4	0.05	0.4	0.7
Second stage	**Agriculture**	**Manufactures**	**Mining**	**Others**
ln(ad valorem costs)	-17.402***	-93.626***	-25.017***	-206.215**
	(1.532)	(1.412)	(2.286)	(77.214)
Observations	42,916	460,132	10,302	354
R square	0.3	0.1	0.3	0.5
Historic Sample				
First stage	**Agriculture**	**Manufactures**	**Mining**	**Others**
ln(great circle distance)	0.008***	0.004***	0.017***	0.005**
	(0.001)	(0.000)	(0.002)	(0.002)
Second stage	**Agriculture**	**Manufactures**	**Mining**	**Others**
ln(ad valorem costs)	-68.275***	-130.247***	-38.558***	-136.360**
	(3.790)	(2.279)	(3.461)	(61.223)
Observations	10,507	87,905	2,740	97
R square	0.2	0.1	0.3	0.5

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

specifications are not strictly comparable complicates their interpretation. Another potential concern in this context is whether distance is a weak instrument.

Appendix C – Estimating the Probability to Export

Our empirical strategy is based on the following Probit specification:

$$Pr(export_{m,y,j} / X) = \Phi(\alpha_j + \beta_j \cdot ln(cost_{m,y}) + fx_s + fx_y) \quad (c.1)$$

Where, $export_{m,y,j}$ is a dummy variable with value one whenever a municipality *m* exports in category *j* (agriculture, mining, manufactures, and

Table C.1 ■ The Impact of Transport Costs on the Probability to Export. Probit, 2007–2010.

ln(cost)	Agriculture	Manufactures	Mining	Others
Weighted average	−0.380***	−0.309***	−0.311***	−0.224***
	(0.034)	(0.030)	(0.030)	(0.037)
Pseudo R-squared	0.1	0.1	0.08	0.1
Simple average	−1.531***	−3.854***	−2.818***	−4.646***
	(0.186)	(0.206)	(0.308)	(0.823)
Pseudo R-squared	0.09	0.1	0.08	0.1
Minimum cost	−0.048***	−0.045***	−0.249***	−0.306***
	(0.012)	(0.012)	(0.012)	(0.031)
Pseudo R-squared	0.08	0.1	0.1	0.4
Modal cost	−0.185***	−0.177***	−0.262***	−0.204***
	(0.015)	(0.015)	(0.018)	(0.033)
Pseudo R-squared	0.09	0.1	0.10	0.2
Median cost	−0.923***	n.a	−0.578***	−0.244***
	(0.035)		(0.023)	(0.029)
Pseudo R-squared	0.3		0.2	0.1
Main cost	−0.213***	−0.185***	−0.290***	−0.227***
	(0.015)	(0.015)	(0.018)	(0.027)
Pseudo R-squared	0.10	0.1	0.1	0.2
Observations	21,444	21,444	21,444	19,088

Note: Robust standard errors in parentheses. Model does not converge when median costs are used to the estimate the impact on manufactures.. *** p<0.01, ** p<0.05, * p<0.1.

others) in year *y*. fx_s are state fixed effects, and fx_y, year fixed effects. *ln(cost)* is the logarithm of the weighted average of transport costs per ton (ad valorem costs would require information on the goods exported, which is not available for non-exporters) from *m* to all used customs (or all customs in sample in the case of non-exporters), or the simple average, the minimum, the mode, the median of those costs, as well as the costs to the main customs (defined by export value). Ideally we would want to use a model with municipality fixed effects to better control for unobserved characteristics, but attempts in this direction could not be estimated because of the size of the sample. The results for the regression with state-fixed effects, presented in Table C.1, suggest a very small impact. For instance, on average a 10 percent drop in transport costs would increase the probability to export by 0.2 percentage points in mining, 0.1 in manufactures and 0.09 in agriculture.

Appendix D – Estimating the Impact of Domestic Transport Costs on the Number of Exported Goods

Our empirical strategy is based on the following Poisson specification:

$$E(nro\_prods_{m,y,j} / X) = e^{\alpha_j + \beta_j \cdot ln(cost_{m,y}) + fx_s + fx_y} \qquad \text{(d.1)}$$

Where *nro_prods* is a count variable of the number of products at the 6-digit HS level in category *j* (agriculture, mining, manufactures, and others) exported by municipality *m* in year *y*. *ln(cost)* is the logarithm of the weighted average of transport costs per ton from *m* to all used customs (or all customs in sample in the case of non-exporters), or the simple average, the minimum, the mode, the median of those costs, as well as the costs to the main customs (defined by export value). fx_s are state-fixed effects and fx_y are year fixed effects. As in the case of the Probit, a model with municipality fixed effects could not be estimated because of the size of the sample. The results of the state-fixed effect regression are presented in Table D.1, which is the source of the data presented in Figure 10.

Table D.1 ■ The Impact of Transport Costs on the Number of Exported Goods. Poisson, 2007–2010.

ln(cost)	Agriculture	Manufactures	Mining	Others
weighted average	−0.422***	−0.420***	−0.485***	−0.510***
	(0.0366)	(0.0362)	(0.0483)	(0.145)
Pseudo R-squared	0.104	0.176	0.110	0.191
simple average	−7.747***	−16.55***	−12.17***	−17.43***
	(0.731)	(1.020)	(1.396)	(4.206)
Pseudo R-squared	0.107	0.228	0.122	0.215
minimum cost	−0.557***	−0.625***	−0.702***	−0.923***
	(0.0311)	(0.0223)	(0.0320)	(0.0902)
Pseudo R-squared	0.314	0.464	0.426	0.571
modal cost	−0.413***	−0.472***	−0.528***	−0.554***
	(0.0308)	(0.0310)	(0.0339)	(0.0963)
Pseudo R-squared	0.125	0.213	0.153	0.226
median cost	−0.556***	−0.553***	−0.576***	−0.476***
	(0.0256)	(0.0274)	(0.0303)	(0.0642)
Pseudo R-squared	0.144	0.216	0.139	0.185
main cost	−0.424***	−0.485***	−0.527***	−0.531***
	(0.0217)	(0.0227)	(0.0264)	(0.0789)
Pseudo R-squared	0.145	0.235	0.173	0.232
Observations	21,448	21,448	21,448	21,448

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix E – Policy Simulations

Figure 12 and Figure 13 are computed using the georeferenced exports-transport costs database described in Appendix A and the estimation results of, respectively, equations b.1 and d.1 (with the minimum-cost customs specification). The figures show the impact of a reduction in transport costs, produced by the investments described in the text, on, respectively, the predicted value and number of exported goods.

In order to include the NLTP projected railways in our multimodal network, we had to make two strong assumptions about the location of the train stations and their links to the road network:

First, since information on the locations of the projected train stations was not available, they were inputed into the network either at 50 km intervals or using the location of existing stations, whenever a section of the projected railways closely matched an existing section. Of the 513 stations inputed, 238 had their locations defined by the original network, and 275 were placed according to the 50 km rule.

Second, the inputed stations were connected to the nearest point on the road network via an inputed road. The costs assigned to these roads corresponded to those of the roads they were linked to.

Appendix F – Estimating the Impact of Domestic Transport Costs on Soy Exports and Producer Prices

To estimate the impact of domestic transport costs on soy exports, we started with a subsample of the georeferenced exports-transport costs database described in Appendix A covering the NCM 8 digits products shown in Table F.1. We then merged this subsample with ESALQ-LOG's freight database SIFRECA (*http://sifreca.esalq.usp.br/sifreca/en/index.php*) to associate a road freight cost to each of the road-based routes for soy exports (municipality-customs) and to validate the actual relevance of these routes. Those municipality-customs pairs that did not find a match in the SIFRECA database were dropped from the sample, except in cases where the state of production matched the reported state in the SRF database and appeared in CEMPRE and PAM as having produced the good in question (See Appendix A).

To estimate the impact on exports of both the operating and freight costs, we used a variation of equation b.1 shown below:

$$ln(exports_{m,c,p,y}) = \alpha + \beta \cdot ln(1 + \widehat{ad\_val\_cost}_{m,c,p,y}) + fx_{m,p} + fx_{m,c} + fx_y + \varepsilon_{m,c,p,y} \quad \text{(f.1)}$$

Where $exports_{m,c,p,y}$ is the exports of the municipality *m* to customs *c* of soy good *p* (8-digit HS) in the year *y; ad_val_cost* is the ad valorem transport costs of shipping soy good *p* from municipality *m* to customs *c* in year *y*, computed either from operating or freight costs; *a* is a constant; $fx_{m,p}$ and are, $fx_{m,c}$ respectively, municipality-good and municipality-customs fixed

Table F.1 ■ Soy products Included in the Sample and Their Shares of Total Soy Exports 2007–2010.

NCM code	Description	Share of Soy exports (%)
12010090	Soya beans, other	63.494
23040090	Other solid residues from the extraction of soya bean oil	26.048
15071000	Crude soya bean oil	8.329
15079019	Refined soya bean oil, other	1.727
15079011	Refined soya bean oil in containers of 5 litres or less	0.223
35040020	Powdered soya proteins	0.132
12010010	Soya beans, seed	0.028
23040010	Flours and pellets from the extraction of soya bean oil	0.012
12081000	Soya bean flour and meals	0.004
21031010	Soya sauce in containers of less than 1kg	0.002
21031090	Soya sauce, other	0.001

effects, fx_y is a year-fixed effect and $\varepsilon_{m,c,p,y}$ is the error term. The results are presented in Table F.2. They are robust to several specifications of transport costs, including distance, but are not statistically significant with municipality-customs-good fixed effects used in (b.1), probably as a result of the much smaller sample size.

To estimate the impact of operating and freight costs on producer prices, we began with a 2007–2010 monthly version of the soy database discussed above, restricted to soybeans (NCM 12010010 and 12010090) to match the price information available. This information comes from ESALQ-CEPEA survey on daily municipal spot prices for soybeans

Table F.2 ■ The Impact of Domestic Transport Costs on the Value of Exports: Pooled OLS, 2007–2010 Soy Sample

	Operating Costs	Freight Costs
ln (1+ ad valorem)	−20.037*** (4.043)	−16.200*** (3.581)
Observations	1,080	998
R-squared	0.653	0.621

Note: *** p<0.01, ** p<0.05, * p<0.1. Fixed effects: Mun-Customs-NCM, Year. Robust standard errors in parentheses. Errors clustered by Mun-Customs-NCM.

Table F.3 ■ The Impact of Domestic Transport Costs on Farmgate Prices: Pooled OLS 2007–2010

	Operating Costs	Freight Costs
ln(costs)	-0.103***	-0.121***
	(0.019)	(0.027)
R-squared	0.896	0.884
Observations	543	518

Note: Robust standard errors in parentheses. Fixed effects: Customs-Month-Year, State-Month-Year. Errors clustered by Mun-Customs-Month-Year. *** p<0.01, ** p<0.05, * p<0.1.

(*http://cepea.esalq.usp.br/english/soybean/*), which we are interpreting as farmgate prices.

The estimation was based on the following equation:

$$ln(price_{m,t,y}) = \alpha + \beta \cdot ln(\widehat{cost}_{m,c,t,y}) + fx_{s,t,y} + fx_{c,t,y} + \varepsilon_{m,c,t,y} \quad \text{(f.2)}$$

Where $price_{m.t.v}$ is the average monthly price of soybeans of; $'cost_{m,c,t,y}$ *is* the transport costs per ton of soybeans from municipality *m* to customs *c* in month *t* and year *y*; $fx_{s,t,y}$ and $fx_{c,t,y}$ are, respectively, state-month-year and customs-month-year fixed effects; α is a constant and $\varepsilon_{m,c,t,y}$, the error term. The results are presented in Table F.3. They are robust to several specifications of transport costs, including distance, but are not statistically significant with more rigorous, municipalities-fixed effects. The limited sample size is likely to be playing a role.

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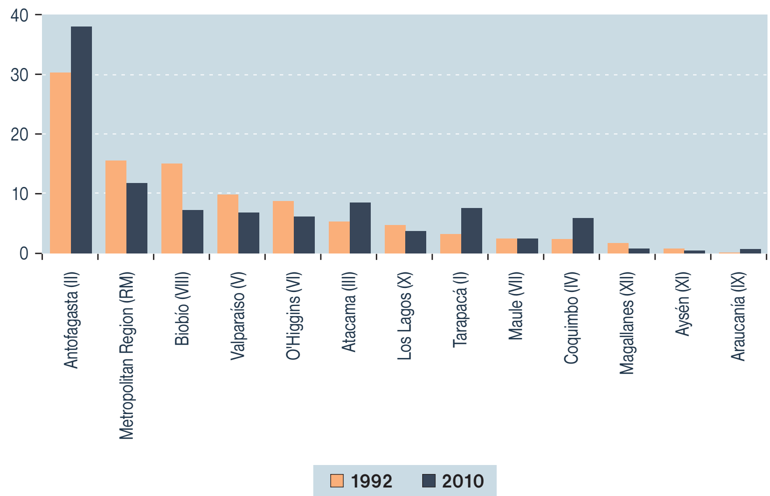
>> Chile: Exporting and the Challenges of Domestic Transport Costs 3

When economists think about trade costs, the word "tariff" first comes to mind. But the large reduction in tariff rates that has taken place over the last two decades has increased the relative importance of other trade costs, such as transport. While the impact of transport costs has been documented in the literature (Hummels, 2001; Clark, Dollar, and Micco, 2004; Mesquita, Volpe, and Blyde, 2008), the focus has been largely on its international component. One would be tempted to assume that the shipping of a good within the country represents only a minor nuisance relative to all the other costs and tasks involved in international trade transactions. Why this is not true is demonstrated by the case of the Chilean brewery Cervecería Austral. From its location in the city of Punta Arenas at the southern tip of South America, the firm must first ship its product by land to the port of San Antonio, more than 3,000 kilometers away. Relative to some of its market destinations, this distance can represent up to 30 percent of the total distance of the shipment. Clearly for Cervecería Austral, shipping the beer within the country represents much more than a minor nuisance.

Examples of internal transport costs that account for significant shares of the total costs of transportation are plentiful, not only in Chile, but also in other countries. It is therefore important to examine the extent to which within-country transport costs constitute an important barrier

FIGURE 1 ■ Export Share by Regions (%)



Source: Based on trade data from MIDEPLAN and Servicio Nacional de Aduanas.

to trade in general and in particular for a country's remote regions. This chapter will focus on Chile.

A quick overview of the export performance of Chile's various regions shows extreme contrasts in terms of export activity.[1] For example, three regions—Antofagasta, Biobío, and the Metropolitan area—account for around 60 percent of Chile's total exports. At the other extreme, regions such as Magallanes—home of Cervecería Austral—account for only 0.8 percent of the total share (Figure 1). In the analysis below, we present descriptive and statistical analyses of the role of domestic transport costs as a factor in the asymmetric participation of Chile's regions in international trade.

The relationship between international trade and regional development is complex and results from the interplay of various centripetal and centrifugal forces. The result of these forces varies from country to country due to differences in endowments, geography, or degree of

[1] Chile's territory is divided in 15 regions (*regiones*), 54 provinces (*provincias*) and 346 communes (*comunas*).

openness. One potential outcome is that the transition from autarky to free trade may encourage firms to sell to the world market and receive some of their inputs from that market, which can lead to a process of deconcentration of economic activity away from the large metropolis. However, not all the theoretical and empirical analyses in this literature predict the same outcomes. Chile has had a very open economy for quite some time. By 1979, for example, the average effective protection rate was below 15 percent and the country's cross-sectoral dispersion in tariff rates was virtually eliminated. Trade protection increased temporarily during the 1982–84 recession, but its commitment to free trade quickly resumed and has persisted until today.[2] While analyzing the impact of this trade opening on the distribution of economic activity across space is not easy, casual observation suggests that the dispersion of economic activity away from the main centers has been slow, as we will see below.

Chile's largest cities are the Santiago metropolis in the Metropolitan region (RM), greater Valparaíso in the Valparaíso region, and greater Concepción in the Biobío region. Together, these three cities account for around 40 percent of the country's population and represent the main economic powerhouses, with the exception of the mining industry. In 1992, these regions accounted for around 40 percent of the country's exports, but by 2010 this share declined to around 26 percent. While part of this drop may have been associated with the process of economic dispersion triggered by the opening of the economy in the late 1970s, the reduction in export shares of these three regions is more related to the boom in mining that has occurred during the 2000s, which has had the effect of increasing the export participation of the mining regions such as Antofagasta, Atacama, Tarapacá, and Coquimbo (see Figure 1). In fact, the participation of RM, Valparaíso, and Biobío—that is, until the 2002 mining boom—only dropped by 2 percentage points when compared to the early 1990s. Therefore, this raw evidence suggests that the trade liberalization process had not produced a rapid and significant deconcentration of economic activity away from the main cities.

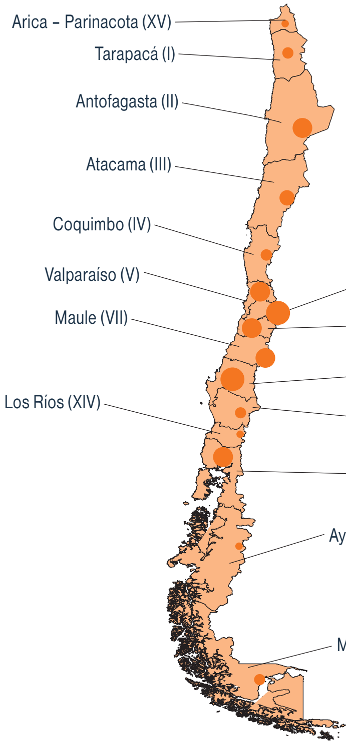
[2] See Tybout, de Melo, and Corbo (1991) and Pavcnick (2002) for details of the liberalization period.

One factor that may explain the persistence in the concentration of production around the large metropolises could be the costs of domestic transportation. Chile stretches more than 4,000 km from north to south, with the main cities located mainly in the middle. It is reasonable to expect that the geographic location of a region, relative to the rest of the country, influences its economic development and potentially its export capacity. For instance, it may cost a great deal to transport intermediate inputs to distant regions. It is also possible that factors of production might be less likely to cluster in a region if it is too isolated from the rest of the country. Thus, lacking a strong comparative advantage—such as copper—the remoteness of a region may constitute an important obstacle to its ability to export to other markets. Figure 2, for example, shows that the lion's share of Chile's non-copper exports originates in the large metropolitan regions in the center of the country. The regions that are distant from the center tend to export much less.

It should be noted that Chile has customs throughout its territory in many ports, airports, and border crossings. In principle, therefore, firms throughout the country could ship their exports through the nearest exit platform to minimize domestic transport costs. Even though many firms are able to do so, more often than not, exports in fact travel long distances within the country before they are shipped to external markets. Table 1 presents information on exports by regions in terms of origin and exit, and for each region of origin shows the main regions through which the exports are shipped out of the country: the region of origin itself, a neighboring region, or another region. It can be seen that a large proportion of these exports is shipped not only through the region of origin or a neighboring region, but through other regions as well. This is the case particularly for regions in the south of the country.

When we identify the country's main exit points we find that around 45 percent of the exports are shipped through the regions of Valparaíso and Biobío. This finding is not surprising, because the port facilities in these regions have the largest capacities of any in the country. Nevertheless, in many cases reaching these ports requires that exports travel long distances within the country before they can be shipped to external markets. Evidence of this can be seen in Figure 3, which shows

FIGURE 2 ■ Regional Exports, 2010
(Percentage share of total exports excluding copper)



Source: Based on GIS map of administrative divisions from DIVA-GIS and trade data from Servicio Nacional de Aduanas.
Note: Excludes copper.

the average distance to customs for the exports of each region.[3] In the north and in the south of the country, these average distances tend to be much greater than those of shipments originating in the middle of the country. Therefore, exporters in different regions of the country face a marked disparity in terms of accessibility to ports, airports, and borders. This brings us to the question raised earlier: to what extent do transport

[3] For each export flow at the 6-digit HS level of each region we first obtain the distance of the least-cost route between the commune of origin and the custom of exit (see Technical Appendix A for details). Then we take the weighted average distance of all the exports of the region where the export shares are used as weights.

Table 1 ■ Percentage of Exports Shipped through Chile's Regions

	Own region	Neighboring region	Other region
Arica-Parinacota (XV)	75	2	23
Tarapacá (I)	93	3	4
Antofagasta (II)	87	3	10
Atacama (III)	52	16	32
Coquimbo (IV)	73	24	3
Valparaíso (V)	95	4	1
Metropolitan Region (RM)	6	89	5
O'Higgins (VI)	0	98	2
Maule (VII)	0	14	86
Biobío (VIII)	91	0	9
Araucanía (IX)	0	90	10
Los Ríos (XIV)	8	33	59
Los Lagos (X)	7	1	92
Aysén (XI)	22	1	77
Magallanes (XII)	74	0	26

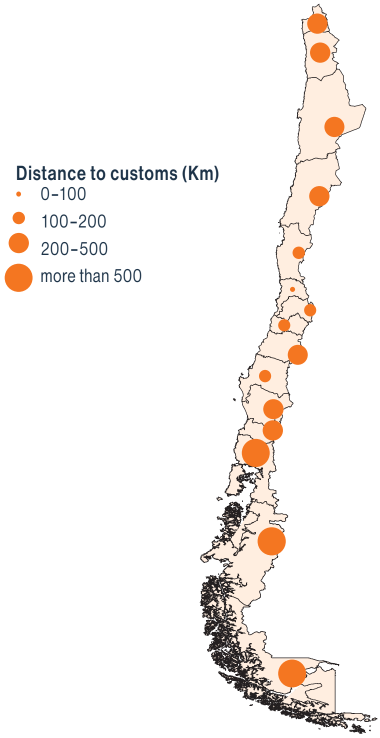
Source: Author's calculation with data from Servicio Nacional de Aduanas.

costs within the country affect the capacity of the regions to trade? In the following subsections we dig deeper into this issue.

The first task is to obtain credible measures of transport costs within the country. As in other chapters in this report, domestic transport costs are estimated by combining spatially georeferenced data on the Chilean road network with truck operating costs to obtain a realistic measure of domestic transport costs. In the case of Chile, data cover the period 2006–2008. The details of the data and the calculations for Chile are presented in Technical Appendix A.[4] The average ad valorem domestic transport costs of the exports are found to be around 3.6 percent, but these costs vary considerably from commune to commune because of

[4] These ad valorem transport costs include only the costs faced by the transport industry and do not reflect other charges, gains, or markups incurred in the shipping activity or differences in market structures across the country. This shortcoming puts a limitation for using these costs to discuss issues about the *absolute* level of domestic ad valorem freights that exist in the country.

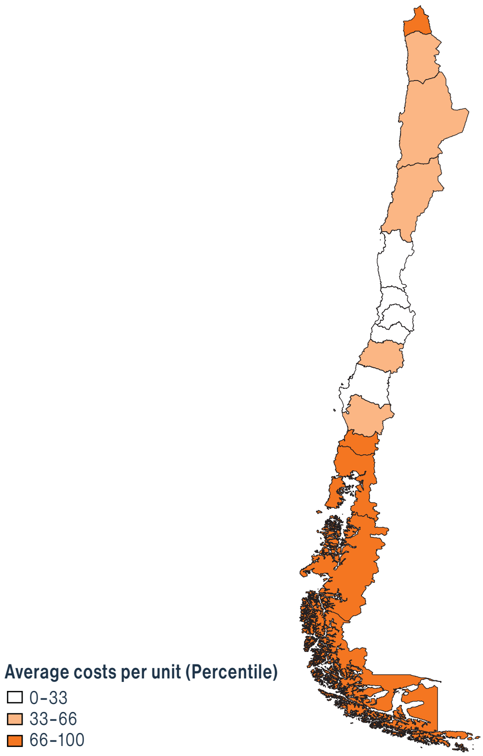
FIGURE 3 ■ Average Distance to Customs



Source: Author's calculations.

the differences in distances that exporters must ship their goods and also because of the characteristics of the goods themselves. For example, Figure 4 shows that the average transport costs per ton for exporters in the middle of the country are much lower than those for exporters in other regions. Measured in terms of percentile, the south faces the highest transport costs, typically above the 60th percentile, while exporters in the middle of the country face the lowest costs. The type of merchandise and particularly the weight of the good are other factors that determine the costs of transportation; exporters of heavy products face high domestic transportation costs. It is then useful to examine differences in the patterns of specialization of the regions to distinguish where different types of goods are produced.

FIGURE 4 ■ Average Transport Costs

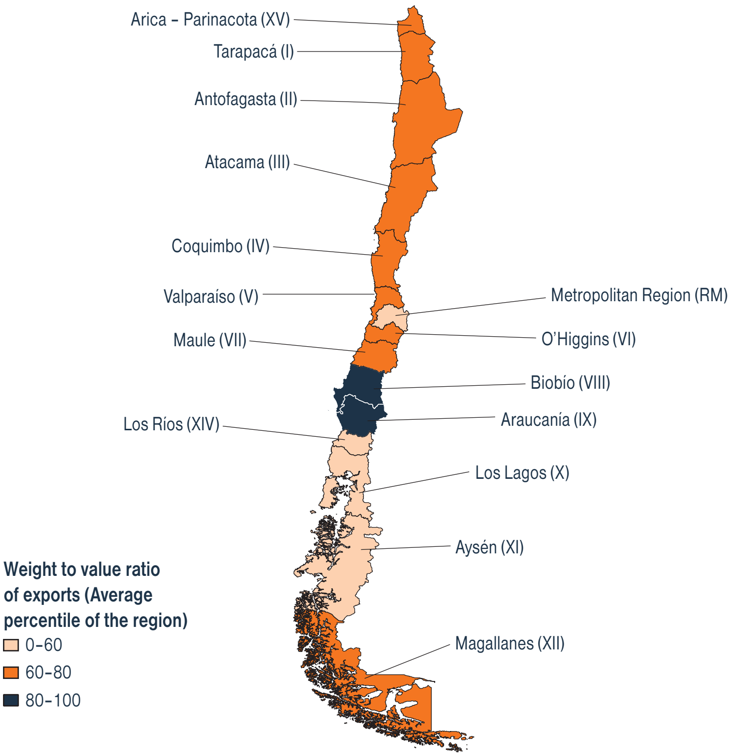


Source: Author's calculations.

Chile's production patterns are geographically well defined. The dominant industries are mining in the north, wineries and cellulose in the center, fishing in the south, and a well-diversified manufacturing base around the metropolitan region. These production patterns translate into regional differences in weight to value ratios. Figure 5 shows the average weight to value ratio of the exports of each region expressed in percentiles. Regions with high percentiles produce heavy goods; regions with low percentiles specialize in lightweight goods.[5] The latter includes

[5] Average weight to value ratios by commodity are constructed at the 6 digit-HS level of disaggregation using trade data for all the countries in the world from 1996 to 2010.

FIGURE 5 ■ Regional Differences in Weight to Value Ratio of Exports



Source: Author's calculations.

regions specializing in fishing and processing fish-related products, such as Los Ríos, Los Lagos, and Aysén. Fisheries products tend to be relatively lightweight, and as such the average percentiles of these regions are the lowest in the country. The percentile for the Metropolitan region is also low, which reflects a diversified set of manufacturing industries that export only limited amounts of heavy commodities. The remainder of Chile's regions exhibit exports with much larger weight to value ratios due to their dependence on heavier resource-based industries. For example, the northern regions of Antofagasta and Atacama have large mining industries; central regions such as Maule are highly dependent on wine exports, another heavy product; and Magallanes in the south produces refined petroleum goods, among other products. Topping the scale are the regions of Biobío and Araucanía, which are highly specialized in the production of pulp and cellulose products that are among the heaviest relative to their values; these regions exhibit average weight to value ratios above the 80th percentile. The general finding from this figure is that with the exception of a few regions, including Santiago, the weight of goods is likely to be an important component of the transport costs for exporters due to the country's reliance on resource-based products.

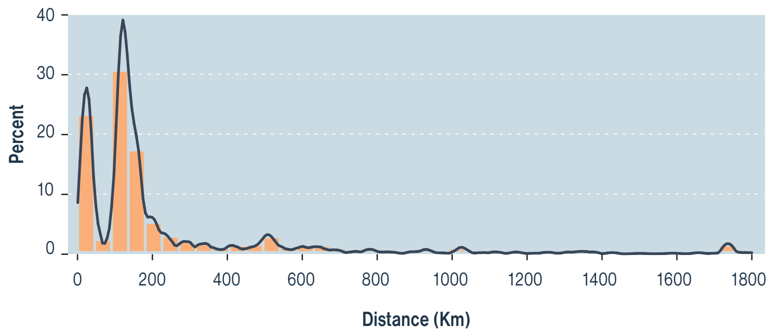
International Trade and Domestic Transport Costs

In our first assessment of the relationship between transport costs and trade flows we examine the distribution of the distances traveled by export shipments from their points of origin to their customs of destination.[6] If most of the exports are shipped over short distances, this would suggest that domestic transport costs might be an important obstacle to trade. The distribution of distances is shown in Figure 6. There is a clear pattern of concentration of exports within the first 200 km from customs. After this, the share drops significantly. Long distances to ports, airports, and border crossings seem to be negatively associated with the export performance of the locality.

Figure 7 further illustrates the negative association between total exports at the commune level and the average distance of these exports to customs. The figure also shows some dispersion in the data. Some communes, for example, have exports that are below the trend line while others have exports above the trend. The main reason for this is that export performance is not solely determined by the costs of transporting goods or the distance to customs. Also influencing the export performance of a location are other factors such as the pool of endowments available, the types of goods produced, or the ports most frequently employed. Therefore, while Figure 7 illustrates the existence of a relationship between distance and export performance, this examination is far from rigorous

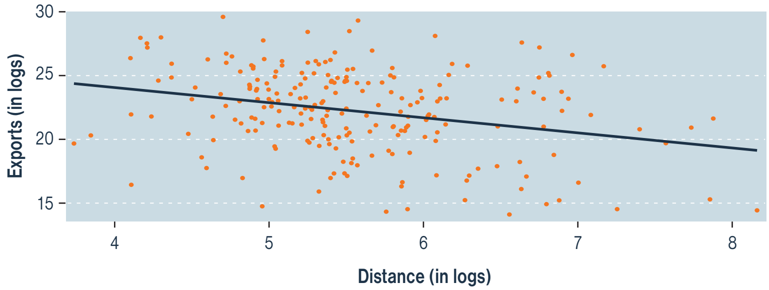
[6] It is constructed with the actual distance from the commune of origin to the port, airport, or border effectively used.

FIGURE 6 ■ Distribution of Domestic Distances Traveled by Export Shipments, 2008



Source: Author's calculations.

FIGURE 7 ■ Commune Exports and Distance to Customs



Source: Author's calculations.

in its ability to demonstrate the impact of domestic transport costs on regional exports. For this purpose we turn to an econometric model that relates the exports at the municipality (commune) and product level[7] to corresponding ad valorem transport costs while controlling for permanent municipality-product-custom characteristics and year-specific factors (see Technical Appendix A for details on the exports dataset). In estimating this equation we distinguish between primary products and manufactures.

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[7] At the 6-digit HS level.

This provides for more flexibility in specification, for example, by allowing the impacts of transport costs on exports to differ across sectors due to differences in their transportability.[8] The outcomes of the estimations are shown in detail in Technical Appendix B. The econometric results indicate unequivocally that exports are negatively correlated with the level of domestic transport costs. All the coefficients are statistically significant and present the right signs. For example, the results indicate that a 1 percent reduction in ad valorem transport costs would lead to a 4.3 percent increase in manufacturing exports.

A potential limitation of this econometric model is the possibility of reverse causality between ad valorem transport costs and trade. Econometrically, this shortcoming can be addressed using, among other things, instrumental variable techniques or by exploiting exogenous sources of variation. We employ the latter strategy in a second model in which we exploit the random and exogenous variation in domestic transport costs associated with the earthquake that took place in Chile in February 2010.[9] The results show that the road damage and the resulting increase in transport costs had a negative impact on the country's export flows (see Box 1). While this econometric approach is different than the econometric model described above, the results indicate that the relationship between exports and domestic transport costs is real and is not produced by reverse causality.

We now use the results from the estimations to simulate the trade impacts associated with changes in transport costs, focusing on the regions with subpar export performance, which are the most remote regions. As explained earlier, the capital of Santiago, as well as the main ports and airport facilities, are located in the central part of the country, while the remote regions are located far from the center. One would expect that exporters in remote regions might make full use of nearby port and

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[8] We also estimate the same regression using additional controls for municipality, product and customs characteristics varying over time. The results, available upon request, are very similar.

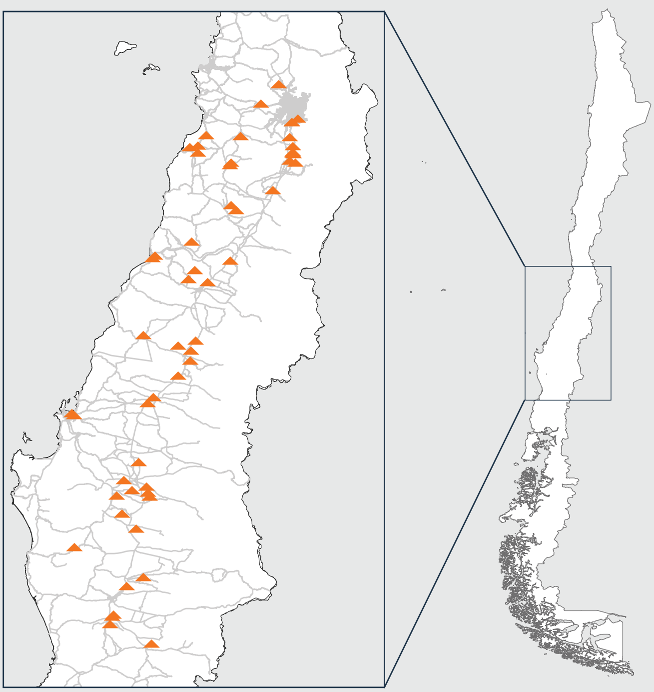
[9] The analysis performs difference-in-difference estimations to compare the group of firms affected by the earthquake before and after the shock with the group of firms not affected by the earthquake. The earthquake event is used as a natural experiment to be able to identify the effects of domestic transport costs on exports.

Box 1: Trade, Domestic Transport Costs, and Chile's 2010 Earthquake

The 8.8 magnitude earthquake that struck Chile on February 27, 2010, was among the eight strongest tremors ever registered. Its epicenter was located about 330 kilometers southwest of the capital of Santiago and about 105 kilometers from Concepción, the country's second largest city. Resulting interruptions of transit over Chile's road network provided an opportunity to use sophisticated econometric techniques to examine the relationship between transport costs and trade flows. A summary of this analysis, carried by Volpe and Blyde (2013), is presented below.

The earthquake damaged many sections of the road network. According to the Chilean Ministry of Public Works, (MOP), a total of 717 points on the public road network were affected, including 396 roads and highways, 90 access roads, and 212 bridges. In addition, 62 points on the road network under private concessions also registered damages. In total, the MOP estimated that 1,554 kilometers were somewhat affected by the earthquake, which represents about 9 percent of the country's total paved road network. Damage ranged from mudslides, which required warnings of caution to drivers, to the collapse of bridges and the complete loss of connectivity. Figure B.1 shows the location of the 55 points in the country's primary and secondary road network where traffic was completely interrupted.

FIGURE B.1 ■ Locations with Complete Road Interruptions



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■ Box 1: Trade, Domestic Transport Costs, and Chile's 2010 Earthquake (*continued*)

The damage forced many vehicles to take detours, which increased costs related to the additional distance and time required to reach destinations. Through an analysis based on geographic information system data, the authors show that median distance to destination for exporters affected by the earthquake increased by more than 30 percent. But while many roads were damaged by the earthquake, others were not affected. Similarly, many firms were forced to utilize alternative routes, but many others were not. Volpe and Blyde (2013) rely on this random and exogenous variation in the domestic transport costs associated with the earthquake to identify the effects of domestic transport costs on exports. Examining 12 months of data, the analysis compares the export performance of the firms whose routes were affected by the earthquake before and after the event to the performance before and after the earthquake of the firms whose routes were not affected. In making the analysis, the researchers made 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 where the exports exit the country.

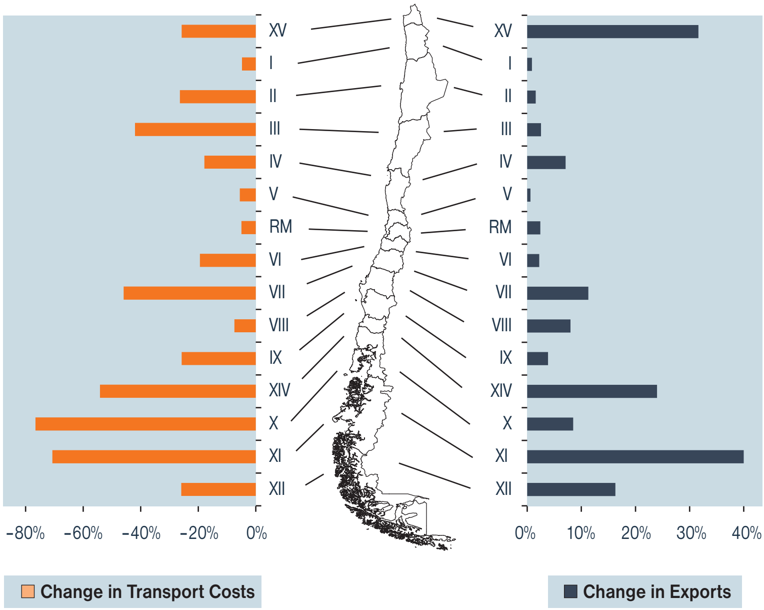
The analysis found that road damages indeed affected the export flows of the country. The exports whose routes were particularly affected had a rate of growth before and after the earthquake 33.7 percent lower than that of their non-affected counterparts. The authors also show that the main cause for this drop is a reduction in the number of shipments, which was particularly serious for large firms. The results show that infrastructure shortages can put a cap on the level of operations to serve foreign markets, thus limiting a firm's ability to benefit from potential economies of scale and gains from trade in general. For details see Volpe and Blyde (2013).

airport facilities instead of incurring high transport costs to the middle of the country, where the goods would be shipped to their final destinations. While some exporters do use nearby facilities, most tend to ship their goods to exit points in the center of the country. Evidence for this was presented in Table 1, which shows that significant shares of exports from the north and south regions are shipped out of the country not from their own regions (or neighboring regions) but from other regions.

Due to the intensive use of logistics facilities in the middle of the country, firms there have lower domestic transport costs than firms in remote regions. To assess the trade effects of the additional burden faced by the regions away from the center we simulate a counterfactual exercise in which we assume that the exporters in remote regions do not face longer routes than their counterparts in the middle of the country. Note that Figure 6 shows a large concentration of exports around 150 km from customs. This corresponds to the typical distance over which an exporter in the middle of the country, such as in Santiago, ships goods to a major port also in the middle of the country, such as Valparaíso. Our counterfactual exercise consists of assuming that the maximum distance transited by any shipment within the country (from point of origin to port) is 150 km. The implicit assumption here is that the country has adequate port, airport, and logistics facilities throughout its territory giving any exporter, regardless of location, similar access to a port of exit as a counterpart in the middle of the country.

As shown in Figure 8, transport costs are reduced least in the middle of the country, in particularly in regions RM, V, and VIII. (The bars (left graph) show the change in the average costs by region.) Exporters in these regions ship most of their exports through ports that are close to their locations because the major logistics facilities of the country are located in these regions. Therefore, the simulation does not represent large savings in terms of distance and time-related transport costs for

FIGURE 8 ■ Percentage Change in Transport Costs and Regional Exports when Distance of Shipment Does Not Exceed 150 km



Source: Author's calculations.

these exports. When we move away from the center, however, the drop in transport costs becomes much greater, decreasing by more than 50 percent in some regions. Clearly, firms in these regions ship a significant portion of their exports over long distances within the country to reach a port; the simulation indicates large savings in terms of transport costs. Note that not all the remote regions located away from the center exhibit large decreases in transport costs. One example is region I. The results for this region are explained by the presence of the port of Iquique and the high concentration of region I's exports that ship through this port. The port of Iquique specializes in the exports of minerals[10] and more than 80 percent of this region's exports are mining-related products. Therefore, even though the region is far from the center, its highly specialized exporters do not travel long distances to reach other logistics facilities, but rather ship most of their exports through this specialized port. But while the port of Iquique is for this region what the logistics services in the middle of the country are for the middle regions, this is not generally the case for other remote regions. Region II, for example, also specializes in mining, and it too has a port—Antofagasta—that is highly specialized in shipping mining products. Relative to region I, however, the exports of region II are more diversified in terms of the number of ports that the region uses for shipping its goods, which explains the larger decrease in transport costs from the simulation.

In Figure 8, the bars (right graph) show the percentage change in exports produced by the simulation. We observe a pattern of impacts similar to the changes in transport costs, in which the central regions generally exhibit the smallest increases in exports while the regions away from the center experience much larger gains. For some of the regions, the increase in exports can be quite substantial—up to 40 percent in some cases.[11] The simulation illustrates the potential convergence effect that could be set in motion if exporters in remote regions could reach adequate

[10] More than 60 percent of the exports passing through this port are mining products.

[11] Because the simulations focus on the goods that are actually exported, the impacts presented correspond to responses in the short term to changes in transport costs and not on the potential benefits that could arise in the long term from improving connectivity. In this sense, our estimates are conservative.

port infrastructure under comparable conditions as their counterparts in the center of the country.

The simulation described above illustrates the positive trade impacts of improving connectivity within the country. Another way to analyze the effects of transport costs on export performance is to study the consequences of losses in the level of connectivity. The earthquake that struck Chile in February of 2010 damaged several sections of the road network, thus providing a rare opportunity to make such an analysis, which is presented in Box 1.

The 2010 earthquake made many routes impassable and forced shipments to be rerouted, which resulted in higher domestic transport costs for exporters using these routes. Using georeferenced data from Chile's Ministry of Public Works indicating the exact location of the road damage, we calculated the alternative routes from communes with positive exports to the exit platforms used by those communes.[12] Figure 9 shows the distribution of distances between production plants and exit nodes before and after the earthquake. The median distance increased by more than 30 percent.

Reduced connectivity certainly had an impact in the export performance of the country. The econometric analysis, which is described in more detail in Box 1, compares affected exporters before and after the earthquake with non-affected exporters. The results show that during the year after the earthquake export products that had to be rerouted increased at a rate 34 percent lower than the exports whose shipments were not affected. This translates into significant export losses. For instance, one year after the event, total annual industrial exports would have been around 6 percent more had the earthquake not occurred. Similar to the previous simulation, this analysis underscores the importance of within-country connectivity on trade outcomes.[13]

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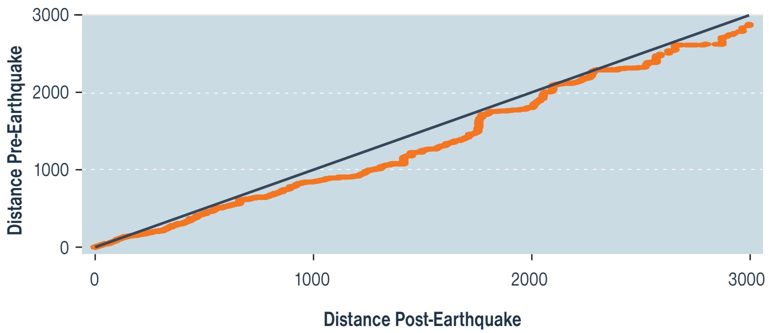
[12] The routes were identified using the same methodology employed to estimate domestic transport costs (see Technical Appendix A).

[13] This event did not necessarily produce more damage on the remote regions of the country relative to the central regions. Indeed, much of the road destruction took place in the middle of Chile. True, many exporters in remote regions use ports in the center as mentioned before, but such exporters must transit long distances to reach the middle of the country.

FIGURE 9 ■ Distribution of Distances Traveled to the Exit Points Before and After the Earthquake



Source: Volpe and Blyde (2013).
Note: The figure is a quantile-quantile graph that plots distances 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.

Policy Actions

Before discussing policy recommendations it should be acknowledged that Chile has a comparatively robust transport infrastructure. For instance, according to the transport infrastructure index reported by the World Economic Forum in 2010–2011, Chile is ranked 37th out of 139 countries worldwide in this respect, which puts it ahead of the rest of Latin America.

The concessions program that Chile embarked upon about two decades ago is clearly one of the reasons behind the country's achievements in this area. Through this program, Chile has expanded and modernized roads, airports, and ports, including the modernization of Highway 5, one of the main arterial roads of the country. Given the results of our simulation, the concessions program is an important endeavor and deserves support. At the same time, however, the program has tended to concentrate on road improvements in the center of the country, near Santiago. The challenge, therefore, is to extend it to other sections of the north-south corridor and to the regional road networks, most of which are currently administered

As such, a significant portion of the overall trip is not affected by the damaged roads. In contrast, almost all of the routes used by exporters in the affected regions were affected.

by the public sector. The earthquake that affected the country in 2010, as mentioned earlier, has also created new demands for construction (see Box 1) that require the cooperation of both the public and the private sector.

The status of the road network is not the only determinant of transport costs. Many other factors also come into play, such as the market structure and the regulations governing the trucking industry. Although a comprehensive assessment of market structures and regulatory issues in Chile is beyond the scope of this chapter, a few examples will serve to illustrate some of the issues involved.

The market structure of Chile's trucking industry is highly atomized, with about 70 percent of the firms owning only one vehicle.[14] These small firms typically have very low levels of formality and professional standards. They usually lack accounting and record-keeping practices, and this lack of information may even result in charging tariff rates that do not cover their long-term costs. Despite lower rates, however, most of these firms do not directly compete with their larger and more efficient counterparts because the former typically engage in transportation activities with low levels of specialization, such as moving construction materials. Larger, more specialized firms tend to serve other segments of the market. The small and relatively inefficient firms, however, are usually associated with some negative externalities of the industry. For instance, their trucks are generally older, consume more fuel, and suffer more accidents than those of the larger firms. This leads to higher congestion, increased time costs, more damage to the roadways, and increased infrastructure costs. For these reasons it is important to remove barriers that prevent these firms from growing and becoming more efficient.

Better business practices would help these small firms to adopt better technology, improve efficiency, and encourage growth. At present, for example, it is difficult for many of these firms to evaluate the advantages of renovating their fleet or engaging in any kind of innovative activity because most of them do not keep records of their own costs and revenues. Incentives to take courses in accounting and record-keeping could be the

[14] According to the Ministry of Transport and Telecommunications.

first step in helping them to realize the opportunities that may lie ahead if they upgrade their physical capital and business operations.

In the area of regulation, several examples illustrate how legislation could also help to reduce transport costs and improve connectivity within the country. One example relates to incentives needed to help small trucking firms grow and become more efficient. In principle, Chile's legislation does not directly shield trucking firms from competition. For instance, there are no regulations on freight rates or impediments to entry. Therefore, market forces provide firms with the necessary incentives to increase efficiency to survive competition or, alternatively, to exit the market. However, some aspects of the regulatory framework may reduce incentives for the trucking firms to grow. One example is a law (No. 19764 and subsequent modifications), which allows all firms to recover part of a specific tax on fuel under a scheme that enables smaller firms to recover a larger percentage of the tax than medium and large firms. While this might not be a big enough disincentive for many companies to expand, this law illustrates why the value of policies intended to benefit the smaller (and normally less efficient) firms should be carefully weighed against all the costs that the policy might generate, including the costs associated with the presence of negative externalities, such as those mentioned before.

A second example in the area of transport regulation is a norm (DFL-30), which mandates shipping firms to employ only storage facilities located in the same districts of the ports they are using. Imposing restrictions on where trucking firms can store their goods clearly limits the abilities of firms to design optimal logistic plans and may result in sub-optimal configurations of routes for transporting and delivering goods. Ultimately, this inefficiency translates into higher shipping prices.

Beyond such regulatory issues, other initiatives could improve the efficiency of delivering goods within the country and reduce the costs of transportation. One is related to the problem of cargo imbalances. In Chile, trucks often travel empty on either the inbound or the outbound trip, which tends to raise the freight rates because the shipper pays for forgone capacity on half the distance traveled. In many instances this is a problem of lack of information; a trucker arriving at a port to deliver a cargo does not know that there is another potential cargo that could be shipped back over the same route (or to another place). Or a shipper in the port does not know that there is an empty truck that could potentially cover the desired route. A solution would be to improve information through cargo-community systems that electronically provide information on origin, destination, time-tables, and truck capacity of all the shipping that takes place among the registered companies. The system helps improve the market clearing process of the shipping community, thus reducing cargo imbalances and freight costs. Such systems have been used extensively in the US and Europe.

Finally, alternative modes of transportation for shipping goods domestically can also increase competition and help to keep freight rates down. While full development of such alternative modes might take some time, some policies could produce almost immediate impacts. One example is removing restrictions on cabotage, in which a foreign-owned vessel transports cargo and passengers among different points in the same country.

At present, foreign ships that unload their cargo at Chilean ports do not have cabotage rights. Recently, however, the government announced the elimination of this restriction, which could increase the supply of carriers available and thus the level of competition, not only for marine transportation but also for land transportation.

In this last section of the chapter we have discussed some potential policy actions that could help reduce freight rates in Chile. Rather than present an exhaustive list of policies for doing so, we have provided concrete examples that could produce the desired results. These examples illustrate the larger point that when it comes to lowering transport costs, it is not all about building roads, but also about soft policies related to regulations, incentives, and issues governing market structure. Finally there are important political economy issues regarding some of these policies, and their discussion goes beyond the scope of this chapter. It should be clear, however, that any attempt to improve the efficiency of the cargo industry would almost certainly require an understanding of such issues.

Technical Appendix

Appendix A – Exports and Transport Costs Datasets

Exports

The export data is obtained at the transaction-level from the Chilean national customs authority, *Servicio Nacional de Aduanas*. Each record includes a firm identifier, the firm's name, its location (*comuna*), the region from which the production originates, the type of good (at an 8-digit HS level), the port, airport, or land border through which the good exits Chile, the export value in US dollars, and the quantity (weight) in kilograms. For some observations, the location of the firm at the comuna level does not correspond to the region of origin. This is because the data on location for some firms correspond to the place where the firm is legally registered instead of the place where the production takes places. This corresponds to 35 percent of the observations. In those cases, we make the necessary adjustments using physical location information taken from directories of various industries including mining, fishery and forestry, as well as a general directory of industries of SOFOFA (Sociedad de Fomento Fabril). For those observations in which the directories were not useful to identify the place of production we applied an algorithm for reassigning the comuna. Based on all the observations in which the comuna corresponds to the region of origin, essentially the algorithm assigned the place of production to that of the comuna with the highest likelihood of producing the particular good and with the highest likelihood of shipping it through the indicated customs. All the econometric exercises that are shown in this chapter were also performed without the group of observations that were adjusted. The results do not change in any significant way.

Transport Costs

We use real distance and time-related cost data taken from an annual survey on the operational transport costs of land cargo services (Encuesta de Servicio de Transporte de Carga por Carretera), which is conducted by the INE. The survey covers trucking firms of all sizes and includes information for each firm on numbers of trucks, capacity, tons carried, distance covered, and operational costs incurred during the year. Table A.1 summarizes the average distance and time-related costs for the year 2008. Fuel expenses are the most significant distance-related cost while wages as well as depreciation costs account for the most significant time-related costs. Panel (3) of the table calculates the total reference cost per ton per km, which is obtained by adding total distance-related costs to total-time related costs once the latter is divided by the average speed of the class-truck selected in the country.

Using these transport costs and the digital map of Chile's road network, the methodology finds the least-cost route between any two points

Table A.1 ■ Operational Transport Costs, 2008

(1) Distance-related costs	
Chilean Pesos per Km per Ton	
Fuel	20.3
Lubricants	1.5
Maintenance	5.4
Tire	2.2
Batteries	0.2
Other	2.4
Total	32.1
(2) Time-related costs	
Chilean Pesos per Hour per Ton	
Wages	90.4
Insurance	8.5
Depreciation	30.9
Permits	3.3
Total	133.1
(3) Total costs	
Chilean Pesos per Km per Ton	
Total	35.43

Source: Author's calculation based on data from INE.

Note: 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 "Transporte de Carga por Carretera" carried by the Instituto Nacional de Estadística (INE). Total costs = (distance_relatedcosts) + (time_related costs/average speed).

(say a city and a port). We apply this method of analysis, which is based on Combes and Lafourcade (2005), to all pairs of origin-destinations of interest—all the communes (origins) and all the active customs (destinations)—to calculate the freight costs of transporting the exports from their location of production to their ports of departure in the country (ports, airports, or borders). These transport costs also incorporate adjustments for the conditions of the roads based on information from the Chilean Ministry of Public Works, which keeps track of conditions on the country's main road network. This adjustment follows the same methodology as the one used in the chapter for Colombia (see Technical Appendix A in that chapter).

Ad Valorem Transport Costs

Once the transport costs of shipping one ton of generic merchandise are obtained for each route, we then calculate the ad valorem transport costs for each product as follows:

$$tc_{jrpt} = (TC_{rpt}) \cdot \frac{w_{jrpt}}{E_{jrpt}}$$

where tc_{jrpt} is the ad valorem transport costs of good *j* that is transported from region *r* to port *p* in year *t*, TC_{rpt} is the transport costs of shipping 1 ton of generic merchandise from region *r* to port *p* in year *t*, w_{jrpt} is the weight (expressed in tons) of good *j*, and E_{jrpt} is its export value.

In addition to the transport costs that depend on distance, the weight to value ratio of the good, and the conditions of the route, the ad valorem transport costs in this chapter also include the ad valorem per day time costs of exports. This is calculated by multiplying a general indicator of time sensitiveness developed by Hummels and Schaur (2007) and the time engaged in the shipment over the domestic route. These time costs are measured on an ad valorem basis. For a description of the time sensitiveness indicator, see Hummels and Schaur (2007).

Appendix B – Econometric Estimation of the Impact of Transport Costs on Trade

The empirical model is based on the following specification:

$$\ln(E_{jrpt}) = \beta_1 \cdot \ln(tc_{jrpt}) + \alpha_{jrp} + \alpha_t + \mu_{jrpt} \qquad (1.B.1)$$

where E_{jrpt} is the exports of good *j* from region *r* to port *p* in year *t*[15], tc_{jrpt} is equal to 1+ad valorem transport costs of shipping good *j* from region *r* to port *p* in year *t*, α_{jrp} is a commodity-region-port fixed effect, α_t is a year fixed effect, μ_{jrpt} and is the error term. β_1 is the coefficient of interest. The equation is estimated separately for two groups of goods: primary products and manufacturing. The product groups are defined according to the WTO classification, which in turn defines goods according to the Revision 3 of the Standard International Trade Classification (SITC). Table B.1 shows the results of the estimations.

Table B.1 ■ Main Econometric Results

Regressor	(1) Primary Products	(2) Manufactures
Ad valorem transport costs	-4.2634*** (0.2811)	-4.3076*** (0.3424)
Commodity-Region-Port Fixed Effect	Yes	Yes
Year Fixed Effect	Yes	Yes
Observations	27,614	65,939
R-sq	0.94	0.92

The table shows OLS estimations of equation 1.B.1 for the period 2006–2008. Robust standard errors in parentheses.***; **; * significant at the 1%, 5% and 10% levels, respectively.

[15] Port here refers to maritime ports, airports, or borders.

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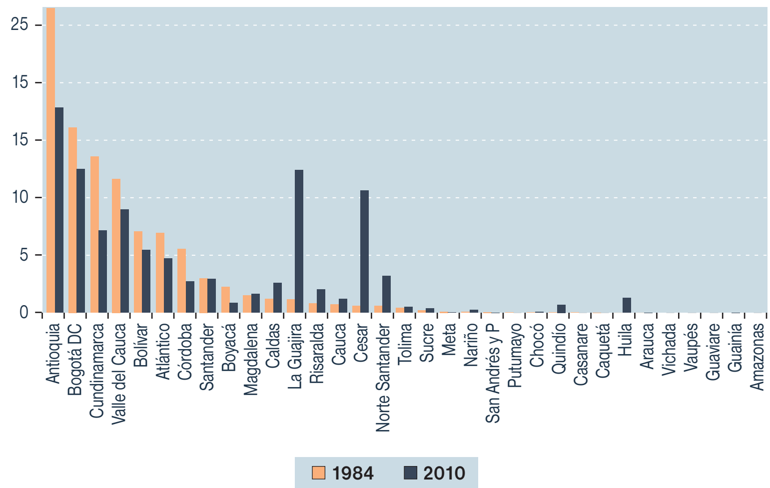
>> Colombia: How Distance and Terrain Affect Trade Performance 4

It is well known that the costs of shipping goods internationally can represent an important obstacle for exporting. It is less known, however, that for many exports, the domestic segments of those shipments can also represent important impediments to trade, as illustrated by the exports of Villavicencio, a municipality in the Meta department located in the center of Colombia. In Villavicencio, agriculture, livestock and mining have been the traditional staples of the economy; however, in recent years an incipient metallurgical industry has also been developed. Before reaching their final destinations, exports of metal products must be shipped first to the port of Cartagena in a trip that entails a distance and time that exceeds 1,100 km and 18 hours, respectively. Clearly, for the exporters of metal products in Villavicencio, the domestic part of the shipment is not a negligible step. This chapter analyzes the complex relationships among trade, domestic transport costs, and regional disparities in Colombia. As with many other countries in Latin America and the Caribbean, export performance in Colombia varies markedly from region to region. For example, Figure 1 shows that just four departments, Antioquia, Bogotá, Cundinamarca, and Valle del Cauca account for approximately half of the country's exports.[1]

[1] Colombia is divided into 32 departments and a Capital District (Bogotá DC). The departments are made up of municipalities.

FIGURE 1 ■ Export Shares by Departments (%)



Source: Departamento Administrativo Nacional de Estadística (DANE) and Dirección de Impuestos y Aduanas Nacionales (DIAN).
Note: The Departments of Amazonas, Guainía, Guaviare, Vaupés and Vichada were officially established in 1991

While these disparities are clearly evident, they are also diminishing over time. In 1984, these four departments produced 68 percent of the country's exports; by 2010, however, their share had dropped to 46 percent. Part of this decline in share is explained by the boom in mining over the last decade that has benefited other departments such as La Guajira, Cesar, and Norte de Santander (see Figure 1). An additional reason for this trend may be Colombia's reduction of tariff barriers since the late 1980s and early 1990s.[2] The relationship between economic concentration and international trade has been thoroughly analyzed both theoretically and empirically in the economic geography literature. Different analyses predict different relationships between trade and concentration, but one of the potential outcomes is that trade liberalization might cause the domestic market to lose its importance relative to the external market in reducing incentives for concentration in the large cities.

[2] See Eslava, Haltiwanger, Kugler, and Kugler (2009) for details of the liberalization period.

Despite the analyses that have been carried out, it is difficult to determine the exact impact of international trade on the concentration of economic activity in the country. Using a computable general equilibrium model, for example, Haddad, Bonet, Hewings, and Perobelli (2008) argue that in the short term, trade liberalization could have led to a larger concentration of economic activity in the center of the country, including the capital, Bogotá,[3] but in the medium to long term (allowing for time for all factors of production to move freely), liberalization may generate a deconcentration of economic activity away from the center. The authors show the existence of a "coastal effect" in which economic activity shifts from the capital to the country's major ports. Data support the existence of this coastal effect. For instance, the mining boom mentioned above reduced the export shares of most of the country's departments (see Figure 1), but these reductions have been particularly large in the metropolitan regions, such as Bogotá and Medellín, and relatively smaller in the coastal departments, such as Atlántico, Bolívar, or Magdalena.

Overall, however, the concentration of economic activity in the main metropolises is still relatively large, which suggests that the reduction in tariff barriers has not produced a significant dispersion of production away from the large centers and particularly towards the non-coastal regions. One explanation could be that trade liberalization alone might have not been sufficient for many of the regions to fully take advantage of opportunities created by foreign trade. There could still be other obstacles, such as high costs of domestic transportation that might prevent certain parts of the country to gain access to external markets and benefit from international trade. To gain some perspective on this issue, we look at the export performance of the various Colombian regions, in this case departments, using the country's political map. This is presented in Figure 2 (top map).[4] The regions with small export shares are shown in light colors while the regions with large export shares appear in progressively darker colors.

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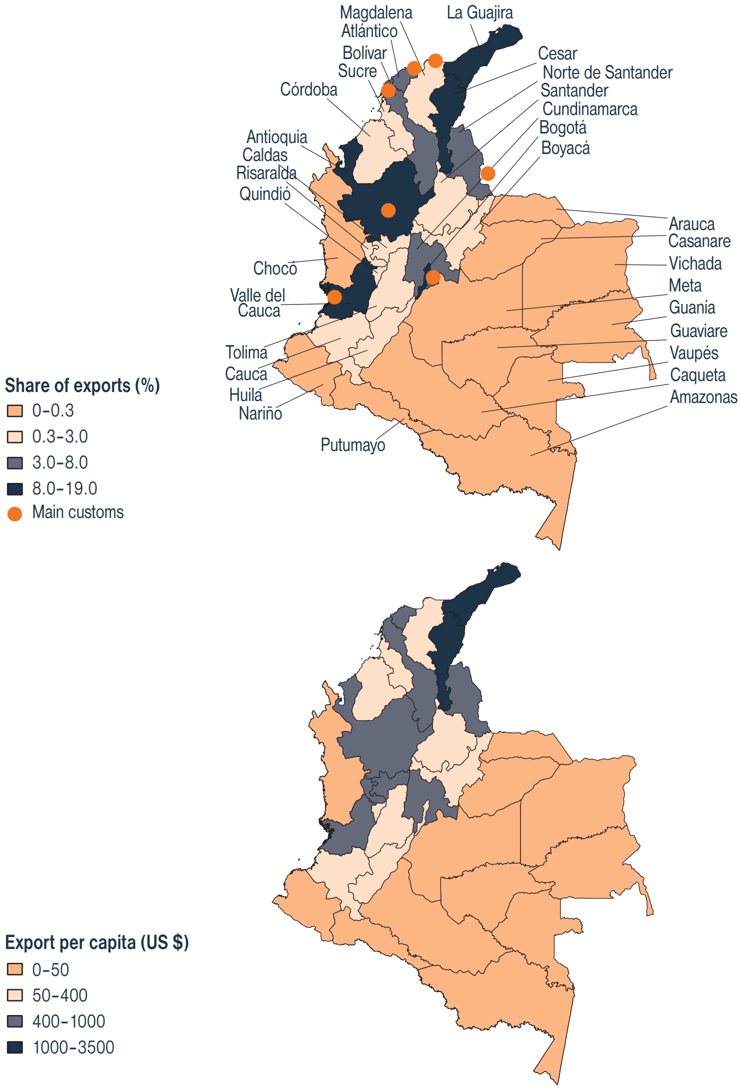
[3] This is mainly the result of a price effect: the regions in the center possess a higher share of imports and so they benefit relatively more from the lower cost of imported inputs.

[4] The region of San Andrés and Providencia (an archipelago) is not shown on the map.

FIGURE 2 ■ Regional Exports, 2010

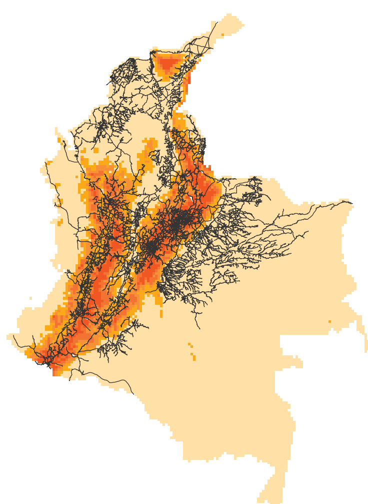


Source: Author's calculations based on information from Departamento Administrativo Nacionalde Estadística (DANE), Dirección de Impuestos y Aduanas Nacionales (DIAN).

The figure reveals immediately that the regions with small export shares, such as Arauca, Meta, Guainía, Casanare, Vaupés, Putumayo, Caquetá, Amazonas, Guaviare, and Vichada (see Figure 1), tend to be located in the southeastern part of the country. Indeed, 11 of the 16 departments with export shares less than 1 percent are located in this region. It is interesting to note that the export shares in these regions are small even after controlling for population size. This can be observed in the bottom map of Figure 2, which shows exports per capita by department.

Part of the explanation is that the exporters in the southeastern part of the country face various obstacles. First, the regions are generally far from the main customs of the country, which are shown in orange circles (in the top map of Figure 2). Second, to reach main customs by land, transportation services normally have to cross the Andes mountains (see Figure 3), which makes transportation more difficult and costly. For example, according to the Ministry of Transportation, the cost of fuel in a mountainous terrain is practically double that in a flat terrain. The map of primary and secondary roads also indicates the existence of regional disparities (see Figure 3). Road density varies across departments, and roads are few or nonexistent in the southeastern region. All of these factors limit connectivity for exporters in remote regions. In the analysis that

FIGURE 3 ■ Topography and Road Network



Source: Author's calculations based on information from INVIAS, LDC, and DIVA-GIS.org.

follows we examine the effect of distance to customs, roughness of the terrain, and density and quality of the road network as factors that limit trade in general, and in particularly the trade possibilities of the remote regions of the country.

The methodology that we employ to measure domestic transport costs is explained in detail in Technical Appendix A of this chapter. The dataset is based on domestic transport costs by truck for the period 2004–2006.[5] The calculation of domestic transport costs takes into consideration the distance from the location of production to the customs used, the roughness of the terrain, the quality of the road network, and also the weight of the good transported. All these factors affect the domestic transport costs. The average ad valorem domestic transport costs of the exports are found to be around 6 percent,[6] but these costs vary greatly depending on the location of the exporter relative to the customs used as well as on the characteristics of the goods produced.[7] In particular, regions far from customs or which specialize in the production of heavy goods can be expected to face high domestic transportation costs.

It is instructive to examine the patterns of specialization in the different regions in Colombia to see where different types of goods tend to be produced. Figure 4 presents information on the average weight to value ratios of the exports of each department, expressed in percentiles. If a department tends to specialize in heavy goods, such as minerals, its average exports will be in the upper percentiles of the weight to value ratio scale. On the other hand, if the department specializes in the production of lightweight goods, such as cut flowers, average exports will be in lower

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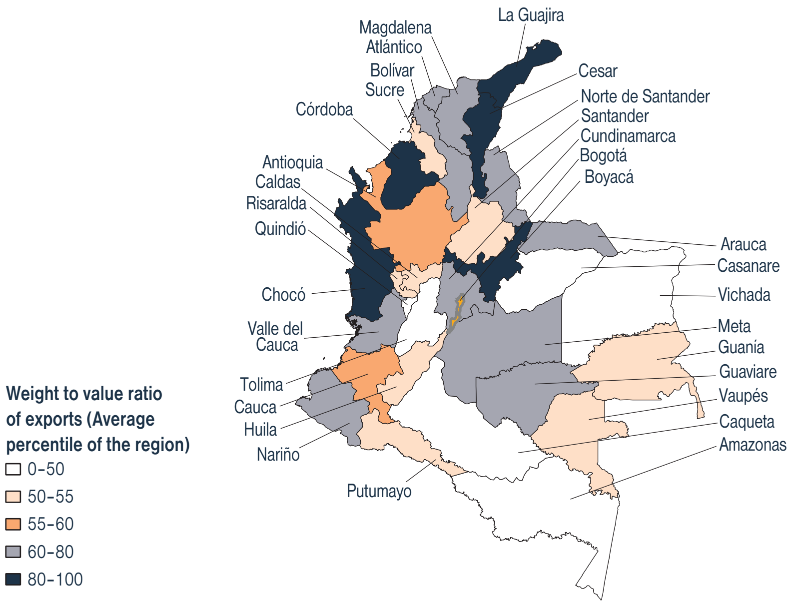
[5] According to the Ministry of Transportation, around 95 percent of all non-coal cargo (in tons) is transported by truck.

[6] This is the weighted average for 2006 in which the exports are used as weight.

[7] These ad valorem transport costs include only the costs faced by the transport industry and do not reflect other charges, gains, or markups incurred in the shipping activity. This implies that the usefulness of this measure lies in the comparison of the relative levels of transport costs across various dimensions more than on their absolute levels. That is, the transport costs calculated here capture the cost variations for transporting goods of different characteristics and from different locations; it is precisely this variation that makes it possible to estimate the trade impact of domestic transport costs, which is the main objective of this report.

FIGURE 4 ■ Regional Differences in Weight to Value Ratio of Exports



Source: Author's calculations.

percentiles.[8] There are clear differences among the departments in terms of the goods that they produce. Some regions, such as Quindío or Vichada, specialize in the production of lightweight agricultural products such as fish, fruits, and apparel. These regions have average weight to value ratios below the 50th percentile. The regions with highly diversified manufacturing production, such as Antioquia or Bogotá, exhibit slightly higher weight to value ratios, but in general they fall below the 60th percentile. Regions with higher percentiles specialize in heavier goods, such as fabricated metal products in Meta or livestock and cattle in Arauca. Finally, regions such as Cordoba, Chocó, Cesar, or La Guajira mainly export mineral products, which tend to have weight to value ratios above the 80th percentile. The figure also shows that relatively heavy goods tend to be exported from the

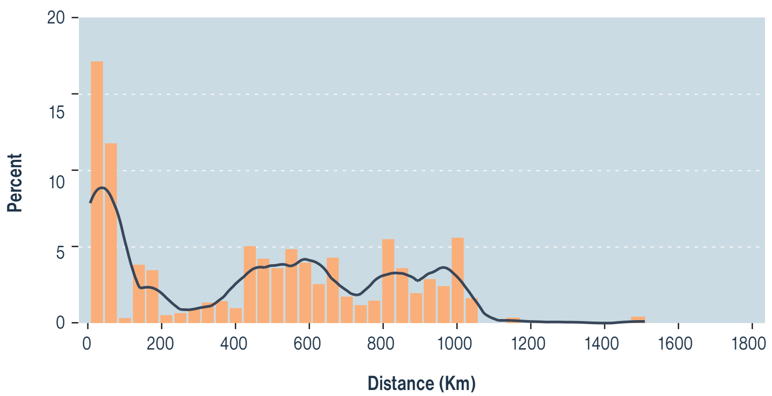
[8] Average weight to value ratios by commodity are constructed at the 6digit-HS level of disaggregation using trade data for all the countries in the world from 1996 to 2010.

northwest part of the country. The southeastern regions, which have most of the lowest export-performing departments, exhibit a mixed picture, with a combination of goods that tend to be in the mid to low range of weight to value ratios. This suggests that the characteristic of the export product literally weighs heavily in the costs of domestic transportation for some of the remote regions, such as Chocó, but it has a much more moderate influence in many of the other remote regions.

International Trade and Domestic Transport Costs

We now examine the association between the costs of domestic transportation and trade flows. An initial examination of this relationship can be done by simply observing the distribution of distances traveled by export shipments from their points of origin to the customs in the country. If shares of exports are more or less evenly distributed across short and long distances, high domestic transport costs might not be an important barrier to trade. However, if most of the exports are shipped over short distances, this could suggest that domestic transport costs might be an important obstacle to international trade as firms are trying to minimize this obstacle by locating their production near customs. The distribution is shown in Figure 5. As shown in the figure, the pattern is clearly not homogeneous. There is a large peak at around 60 km, with subsequent smaller peaks at around 600 km, and 900 km. This evidence can be interpreted as follows: many exports originate in municipalities close to international ports or airports, and these tend to travel over domestic distances no greater than 150 km. The city of Cartagena, with one of the major ports in the country, is an example. Major cities like Bogotá or Medellín, with large international airports, also explain this initial peak. The subsequent peaks in the figure tend to correspond to distances again from large cities such as Bogotá or Medellín to the main ports of the country. For instance, the distances between Bogotá and the ports of Buenaventura and Cartagena are around 520 km and 980 km, respectively. The distance between Medellín and Cartagena is around 650 km. Therefore, even though some of the large cities have their own international airports, they also use main ports that are

FIGURE 5 ■ Distribution of Distances Traveled by Export Shipments, 2006



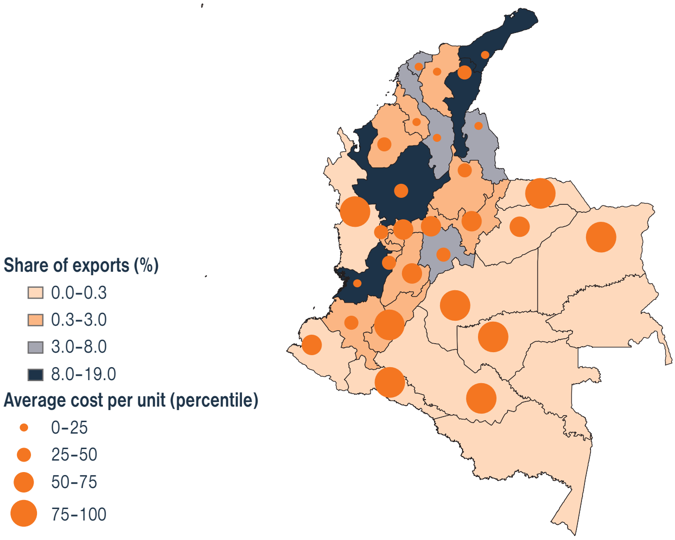
Source: Author's calculations.

not necessarily close to them. Overall, however, we observe a general downward pattern in the distribution of distances with larger shares at short distances from customs and smaller shares at longer distances. Therefore, the figure conveys a simple message: greater distance from ports, airports, and borders is negatively associated with the export performance of the locality.

Additional evidence is presented on the political map of Colombia in Figure 6, which shows the level of exports at the regional (departmental) level and the average transport cost per ton to customs.[9] In general, regions located far from customs and typically with the highest costs (the largest circles) tend to have the lowest levels of exports (lighter colors). This again indicates that the trade performance of remote regions is hampered by distance and consequently by domestic transportation costs. It should be observed that the relationship between transport costs and export performance is not necessarily linear. In the figure, for example, the

[9] The departments of Amazonas, Vaupés, and Guainía—the departments without circles in the map—are not connected with the rest of the country through the existing network of primary or secondary roads. Therefore, it is not possible to calculate land transportation distance from these departments to the various customs of the country. These departments use other modes of transportation (e.g. air) in other to reach the main customs.

FIGURE 6 ■ Regional Exports and Average Transport Cost to Customs



Source: Author's calculations.

regions that export more do not always have the lowest costs (the smallest circles). The reason is that there are many other factors that determine the magnitude of a region's export flows. In the case of Colombia, for example, there was an initial concentration of economic activity in the center of the country that dated to Spanish colonial times, when international trade was not a development priority.[10] This high concentration of economic activity explains, in part, the high volume of exports from large cities like Bogotá or Medellín (in Antioquia) that are not necessarily close to ports. True, these two cities have international airports, which indeed are a factor in their sizeable export shares. However, the shares of exports shipped through their airports are around 30 percent in the case of Bogotá and 40 percent for Medellín. In other words, these cities continue to use ports for most of their exports even though utilizing airports cuts the

[10] Bogota was founded after Spanish expeditions traveled from the coastal town of Santa Marta along the Magdalena River in search of gold, but settled on fertile land that was already inhabited by indigenous people.

distance of the shipment by around 10 times for both cities. Thus, while access to an airport represents an advantage, it is not a practical solution for many exports, especially those that are heavy or bulky.

The historical explanation for economic concentration in Bogotá and Medellín puts in perspective a general notion that there are many factors that influence the export performance of a region in addition to domestic transport costs. A proper analysis that examines the relationship between regional exports and domestic transport costs needs to control for these other factors. In what follows, we perform a careful econometric exercise that takes these additional factors into consideration.

For measuring the effect of domestic transport costs on regional exports we design an equation that relates municipal exports at the product level[11] with the corresponding ad valorem transport costs while controlling for permanent municipality-product-custom characteristics and year-specific factors. The equation distinguishes among agriculture, mining, and manufacturing exports to allow for different impacts across sectors due, for instance, to differences in their transportability (see, e.g., Hummels, 2001). The resulting estimations, which are shown in detail in Technical Appendix B, clearly indicate that exports are negatively correlated with the level of domestic transport costs. All the coefficients are statistically significant and present the right signs. For example, a 1 percent reduction in ad valorem transport costs would lead to a 7.7 percent increase in manufacturing exports.[12]

A potential limitation of this econometric model is the possible existence of reverse causality between ad valorem transport costs and trade. This can occur, for instance, if the government favors transport-related investments in regions that are already exporting successfully. One way to minimize this limitation is to work only with historic municipalities and historic ports. The argument is that the location of historic sites predates the present day influence of international trade on the location of the

[11] At the 6-digit HS level.

[12] We also estimate the same regression using additional controls for municipality, product, and customs characteristics varying over time. The results do not change in any significant way.

exporters or shipping platforms. Similarly, we can employ great circle distances instead of true distances to minimize the potential bias generated by the government actions that favor transport infrastructure projects in some regions over others. We rerun the econometric model using only municipalities and ports created prior to the year 1800 and employ great circle distances to construct the associated ad valorem transport costs. The resulting elasticities for agriculture, mining, and manufactures are not very different from the elasticities shown in Technical Appendix B.[13]

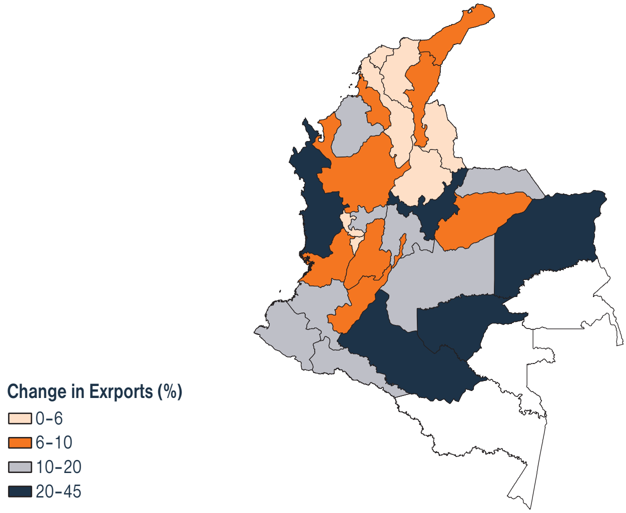
We then put the results of the econometric estimation in perspective by presenting a series of counterfactual simulations. The idea is to assess how much the export performance of the regions would change by improving road infrastructure. Our first simulation consists of a hypothetical scenario in which the average exporter in each region faces a reduction in domestic transport costs from current levels to the lowest 25th percentile, which is similar to the transport costs faced by the average exporter in a coastal department such as Magdalena.[14] The change in exports is shown in Figure 7.[15] The counterfactual generates considerable increases in exports in some of the departments. The largest gains tend to occur in the southeastern part of the country, where average export increases range from 10 percent to 45 percent. Coastal departments, such as Bolivar or Atlántico, and departments with important customs on the Colombian border, such as Norte de Santander, exhibit the smallest increases as their

[13] In particular, the coefficients for agriculture, mining, and manufacture are –5.69, –5.58 and –7.58, respectively, and they are significant at the 1 percent level. Using historic municipalities and ports, we also run regressions entering the great circle distance directly into the regression while controlling for permanent municipality-product and custom-product characteristics as well as for year-specific factors. The results show negative and significant trade elasticities with respect to distances for the three sectors in the range of –1.17 to –0.82. We also run similar regressions with real distances instead of great circle distances and with all the municipalities and ports. The trade elasticities are comparable to the previous case, falling in the range of –1.12 to –0.66. Results are available upon request.

[14] We identify the route with the domestic transport cost (pesos per kg) in the 25th percentile and assign this transport cost to all exports with transport costs higher than this level. Then we recalculate the corresponding ad valorem transport costs of each shipment by multiplying this cost by the weight to value ratio of the shipment. With the new ad valorem transport costs we then examine the impact on exports resulting from the estimated model.

[15] The simulation implies an average reduction in ad valorem transport costs across departments of 40 percent.

FIGURE 7 ■ Average Change in Exports from Reducing Transportation Costs to the Lowest 25th Percentile

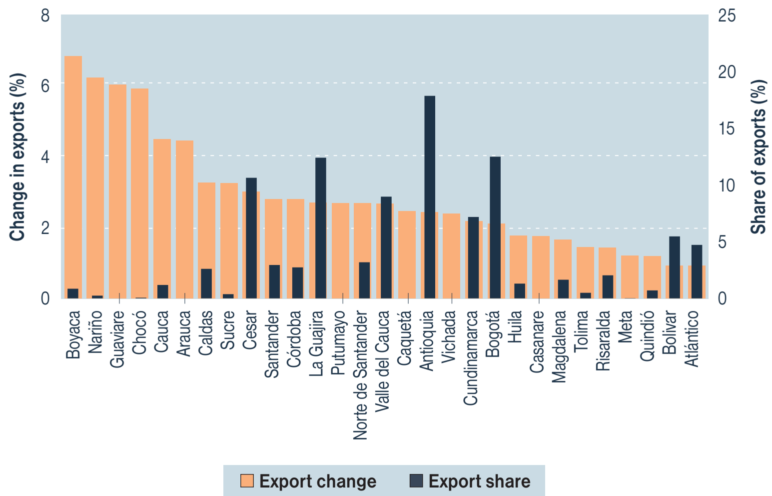


Source: Author's calculations.
Note: The departments of Amazonas, Vaupes, and Guainía (in white) are not included in the simulation because of lack of land connectivity (see footnote 10).

transport costs. The exercise highlights the "catching-up effect" that could be triggered if exporters in remote regions could reach adequate exit platforms in comparable conditions as their counterparts in coastal regions.

Figure 8 presents a second simulation of the trade impact of reduced transportation costs achieved by improving the conditions of all the roads identified as "bad" and "fair" by INVIAS (the national road authority) to good (see Technical Appendix A for details on how transport costs vary by road conditions). It should be noted that in 2005—the year we used for information on road conditions—47 percent of the primary road network under the jurisdiction of INVIAS was in good condition, 33 percent was in fair condition, and 20 percent was in bad condition. The simulation generates an average reduction in ad valorem transport costs across departments of 14 percent. The effects of this simulation over the exports are generally small, although not necessarily negligible. For some regions, the increase in exports is on the order of 7 percent, not a marginal effect considering that the counterfactual implies only

FIGURE 8 ■ Average Change in Exports from Road Improvements



Source: Author's calculations.

improvements of the existing road network and not the construction of new roads. Some of the largest gains are found in regions with very small export shares (left part of Figure 8), while the smallest gains occur in the coastal departments of Bolívar and Atlántico, which have considerably larger participations in trade. The simulation highlights the point that road conditions are not the same across the country and that their improvement could provide particular benefits to some of the underperforming regions.

It is worth mentioning that our calculations for both simulations should be viewed as conservative. They represent only short-term responses to changes in transport costs, because we are assuming that everything else stays the same. For instance, we are only estimating the effect of lower freight costs on products that are actually exported; we are not examining what would happen with other products that could eventually be exported as a result of the lower costs.[16]

[16] The reduction in transport costs generated in the second simulation is also likely to be on the conservative side for two additional reasons: first, we do not have information on

The simulations confirm the argument that domestic transport costs limit the ability of remote regions to take advantage of the opportunities from international trade. True, some remote regions lie far from the oceans, but more and better roads or closer port-airport facilities can generate an impact on their trade performance by reducing their costs to access foreign markets. At the same time, the simulations remind us that transport costs are not the only factor that determines export success. Some regions might never become true export champions, and building roads to nowhere is clearly not a way to spend limited resources. The rationale to bring a region closer to international markets by lowering its domestic transport costs clearly depends on other elements that also affect its potential to trade successfully (endowments, climate, topography, etc). The more general message is that connectivity is a fundamental factor if a region intends to participate more actively in international trade.

What Can the Government Do?

The above simulations confirm that high domestic transportation costs act as a significant trade barrier in the country, and they particularly penalize the regions that are far from adequate port or airport facilities. Policy-driven changes in transport costs, such as those derived from road improvement or investing in new roads, can have beneficial effects. Therefore, domestic transport infrastructure, beyond its primary role of connecting individuals, goods, and production factors within the country, also has significant impacts on the trade capacity of the country and its regions. As such, fostering trade, and in particular improving the chances of less developed regions to benefit from international trade, is highly dependent on the quality of transport-related infrastructure.

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the quality of the secondary road network of the country even though it—together with the primary road network—is used to select the least-cost routes. For all the roads of the secondary network we have made the conservative assumption that they are all in good condition. Second, the information about the quality of the primary road network is limited to the roads under the jurisdiction of INVIAS, the public entity in charge of the road network. This excludes the roads under concession contracts with the private sector. Roads under concession contracts in the primary network represent 17 percent of all the roads. Once again, we have made the conservative assumption that all these roads are in good condition.

We should note that improving trade prospects is not the only objective for which roads are built. The decision-making process to invest in roads involves many different factors and serves many different aims. Therefore, for both trade- and non-trade-related reasons, it is clear that the country's transport infrastructure must be improved. Colombia's road network is generally not very dense; at 15 km of roads per square km of land, the density is significantly below the world average of 87 and even below the Latin American average of 45.[17] Moreover, the existing network suffers from clear shortcomings, including many one-lane roads as well as narrow passes that tend to slow traffic and limit truck sizes. More tunnels, bridges, and two-lane roads are needed to overcome these deficits. But as mentioned above, Colombia has one challenge it must face to a greater degree than most other countries: its geography. Mountainous terrain makes building new roads and maintaining existing ones a much more expensive endeavor than in countries with flatter topography. As a result, the country must spend more per kilometer of transport infrastructure than other countries in order to maintain and build similar levels of density of its road network. These expensive investments can hardly be undertaken by the public sector alone. Public and private partnerships will be essential to improve the transport connectivity within Colombia.

Colombia has made great progress in recent years in providing the country with a much better road infrastructure. Initiatives such as Plan 2500, Ruta del Sol, and Autopista Transversal are recent examples of ambitious infrastructure projects, some of them with important private sector involvement. In the second semester of 2012 the government announced a new round of concessions for about US$20 billion for road projects in the departments of Cundinamarca, Antioquia, and Valle del Cauca. These developments are steps in the right direction and should be continued, but special efforts should also be made to lower the high transport costs for remote regions if they are to take better advantage of the gains from international trade.

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[17] Source: World Development Indicators of the World Bank.

Beyond Roads

Maintaining existing roads and building new ones, albeit important, are not the only mechanisms for lowering transport costs. For instance, the market structure of the transport industry can be a key determinant of freights (Hummels, Lugovskyy, and Skiba, 2009). It is well documented, for example, that the bargaining power of truck drivers or the existence of informal barriers to entry can affect the level of a country's domestic transport costs. Following is a summary of the most salient features of the market structure of the trucking industry in Colombia.

Colombia's trucking industry is highly fragmented with many one-truck firms that are relatively inefficient. The cargo fleet is on average 24 years old—almost 10 years older than the optimal international standard—and operates at only 50 percent capacity (in weight).[18] This suggests an excess of supply over demand. The core of the problem has been historic: an excess of regulation in which freight charges were set by the government according to average truck costs, a practice that tends to penalize the most efficient units. Normally, freight charges could not be negotiated between producers and cargo carriers based on factors such as volume or long-term contracts. Therefore, the system has been traditionally geared towards shielding the small and relatively inefficient units from potentially lower freight charges that could arise from scale economies, innovation, or price competition, among other factors. The government has been well aware of this problem, and in 2007 it issued a national policy, the National Policy for Road Freight Transport (Conpes 3489) that, among other things, contains general guidelines for moving towards deregulation of the industry under the principle of intervening only in the event of market failures. This plan is clearly a move in the right direction.

While improving the road network and modernizing the trucking industry appear to be main policy priorities, the government should not lose sight of the potentialities offered by alternative modes of transportation. Besides opening viable alternatives for shipping goods, alternative modes of transportation would increase competition in the trucking

[18] According to the Ministry of Transportation.

industry and help keep its freight charges in check. One mode with large potential in Colombia is fluvial transportation. The country has more than 16,000 km of navigable rivers. For example, the Magdalena River connects locations in the middle of the country with the main ports in the north (see Figure 9). Similarly, the Meta River offers great potential importance for the country's lagging southeastern regions; this river connects with the Orinoco river in Venezuela and could eventually become an alternative route for trading goods with this country as well as a trade platform for reaching the Atlantic Ocean.

Large investments would be needed in order for fluvial transportation (and other modes) to become a viable alternative. For example, transport operators on the Magdalena River currently face severe draft restrictions that, frequently force them to limit or partition their cargo. Significant investments in dredging, channeling, sediment control, and

FIGURE 9 ■ Fluvial Resources

Source: Author's calculations.

navigation aids, among other things, would be required on this and other rivers to fully exploit their potentialities. Additionally, encouraging firms and agents to use various modes of transportation may require the design of an integral strategy of multimodality. For example, although the Magdalena River has the capacity to move cargo through an extensive section of the country to the ocean and vice-versa, it does not connect directly to large production centers. Therefore, using this river to its full extent requires the creation of transfer connections using multimodal transportation. Legislation may be needed to encourage the complementarity of the various transportation modes. Again, the participation of the private sector would be fundamental to the success of all these projects.

Colombia has already grasped the urgency of this more comprehensive logistics agenda that goes beyond roads, and has already issued a national plan on logistics, the National Logistics Policy (Conpes 3547). The policy provides guidelines for improving the national logistics platform, including strengthening the institutional and logistical information framework and spurring intermodal transport and specialized logistics infrastructure. Much work lies ahead to make this ambitious agenda a reality.[19]

[19] The IDB is supporting the National Logistics Policy and the National Policy for Road Freight Transport with various operations.

Technical Appendix

Appendix A – Exports and Transport Costs Datasets

Exports

The export data are obtained from the Colombian national customs authority, the Dirección de Impuestos y Aduanas Nacionales. Each record includes the municipality as well as the department from which the production originates, the type of good (at a 10-digit HS level), the port, airport, or land border through which the good exits Colombia, export value in US dollars, and the quantity (weight) in kilograms. For some observations, the location at the municipality level does not correspond to the department of origin. This is because the information on location that some firms report corresponds to the place where the firm is legally registered instead of where the production physically takes places. This corresponds to 25 percent of the observations. In those cases, we make the necessary adjustment using an algorithm that combined information from the trade observations in which the municipality and the department matched with information from the Census 2005 carried out by DANE (which includes data on employment by municipality and industry). Based on all the trade observations in which the municipality indeed corresponds to the department of origin, essentially the algorithm first identifies all the municipalities that produce the particular good and that ship it through the indicated customs. From this group it then selects the municipality with the largest concentration of workers in that economic activity based on the Census data. All the econometric exercises shown in this chapter were also done without the group of observations that were adjusted. The results do not change in any significant way.

Transport Costs

The truck operating costs used here are taken from the Colombian Ministry of Transportation which, in turn, are collected from transportation surveys conducted by the same ministry. These costs can be grouped by costs dependent on distance (e.g., fuel, tires) and costs dependent

Table A.1 ■ Operational Transport Costs, 2006

(1) Distance-related costs	
Colombian Pesos per Km per Ton	
Fuel: Flat terrain	57.0
Fuel: Undulating terrain	80.8
Fuel: Mountainous terrain	117.7
Fuel average	85.2
Tires	17.8
Maintenance	38.2
Total	141.2
(2) Time-related costs	
Colombian Pesos per Hour per Ton	
Wages	484.7
Insurance	324.7
Depreciation	380.2
Taxes	4.7
Parking	38.0
Total	1,232.3
(3) Total costs	
Colombian Pesos per Km per Ton	
Total	182.23

Source: Author's calculation based on data from the Ministry of Transportation, Colombia.
Note: The table presents the costs of operating a truck type C-2 in Colombia according to cost figures given by the Ministry of Transportation. Total costs = (distance-related costs) + (time-related costs/average speed).

on time (e.g., wages, depreciation). Table A.1 presents a summary of these costs for the year 2006.[20]

For instance, fuel costs in mountainous terrain are practically double those on flat terrain; these fuel costs on average are the most significant of the distance-related costs. As such, the geography of the country can significantly impact the costs of moving goods. Panel (3) of the table calculates the total reference cost per ton per km, which is obtained by adding the total distance-related costs and the total time-related

[20] These costs vary by class of truck and year. The class of truck chosen for this study, C-2 is the most popular class used in the country.

costs once the latter is divided by the average speed of the class of truck selected in the country.[21]

The methodology uses these transport costs and the digital map of the country's road network to find the least-cost route between any two points (say a city and a port). We apply this methodology, which is based on Combes and Lafourcade (2005), to all pairs of origin-destinations of interest, namely all the municipalities (origins) and all the active customs (destinations) to calculate the freight costs of transporting the exports from their location of production to their ports of departure in the country (ports, airports, or borders). These transport costs also incorporate adjustments for the conditions of the roads, which are explained next.

Adjustment of Transport Costs to Road Quality: Adjustment of Speed

The roughness of roadways is generally defined as irregularities in the road surface that adversely affect the ride quality of a vehicle and thus the user. Roughness is an important road characteristic because it impacts not only ride quality but also vehicle times and maintenance/repair costs. The measurement of road roughness is a relatively new practice that is spreading rapidly thanks to the development of the International Roughness Index (IRI), a standard scale produced by the World Bank in the 1990s (UMTRI, 1998). This is now the most common measurement used worldwide to describe road roughness.

IRI is based on the average rectified slope, which is a filtered ratio of a standard vehicle's accumulated suspension motion (in millimeters) divided by the distance traveled by the vehicle during the measurement (meters). Therefore, IRI is commonly expressed in millimeters per meter (mm/m) or in meters per kilometer (m/km).

While the IRI has an open-ended scale, it typically ranges from 0 (mm/m) to 20 (mm/m) where zero implies an absolutely smooth road surface. Normally, the IRI corresponds to road quality as follows: below 1.7 for airport runways and superhighways; 1.7–3 for new pavements and

[21] Obtained from estimates by the Ministry of Transportation.

older pavements in good condition; 3–9 for roads with surface imperfections, including some older pavements, some damaged pavements, and some maintained unpaved roads; 9–14 for roads with frequent shallow depressions that in some cases could be deep, including some damaged pavements, some maintained unpaved roads, and some rough unpaved roads; and more than 14 for unpaved roads in erosion gullies or deep depressions. For a detailed discussion on the IRI, see UMTRI, 2002.

The Colombian national road authority, the Instituto Nacional de Vías (INVIAS), keeps track of the conditions of the country's primary roads. The institute divides the conditions of each arc in the primary road network in broad categories as "good," "fair," and "bad," and measures these conditions through visual inspection. The broad categories used by the INVIAS roughly match those of the IRI as follows: good (0–3), regular (3–9) and bad (9–14), where the numbers in the parentheses correspond to the IRI.

It is useful to match the INVIAS categories with those of the IRI because it allows us to use other transport studies to adjust vehicle speed and transport costs to roadway conditions based on IRI criteria.

The first adjustment we make is related to vehicle speed. It is natural to think that vehicle speed is negatively associated with the roughness of roads, but without taking speed measurements directly on the roadways, it is difficult to assess how much drivers actually slow down when the conditions of the roads deteriorate. One way to go about this is to assess how road quality determines the quality of the ride. In this area several international guidelines have been developed for health-related reasons. For example, ISO 2631-1 defines how to quantify the impact of human whole-body vibration (WBV) on the health and comfort of the driver and passengers. These guidelines have been used to derive maximum speed limits. In one interesting application of these guidelines carried by Ahlin and Granlund (2002), the authors estimate a relationship between road roughness (measured in terms of the IRI), vertical human WBV, and vehicle speed, and combine it with ISO guidelines to convert WBV limits to corresponding approximate limits for IRI and/or vehicle speeds.

Starting with the quantification of human WBV, this measurement is normally expressed in terms of the frequency-weighted acceleration at the seat of a seated person or the feet of a standing person and can be measured in units of meters per second squared (m/s^2). According to ISO 2631, the base reaction level for WBV is called "not uncomfortable," and goes from zero (0 m/s^2) up to 0.315 m/s^2. Over that level, the reaction is expected to be "a little uncomfortable." When the exposure exceeds 0.5 m/s^2, the reaction is expected to be "fairly uncomfortable." This level coincides with the limit used by the European Union in the EU Machinery Directive. When the exposure exceeds 0.8 m/s^2, the reaction is categorized as "uncomfortable." Daily exposure at this level is likely to cause long-term health effects (see the section about health evaluation in ISO 2631). An exposure above 1.25 is termed "very uncomfortable"; 8 hours daily exposure at this level is illegal in many countries. Finally, an exposure above 2 m/s^2 is called "extremely uncomfortable."

Ahlin and Granlund (2002) use these guidelines in their calculation in a mathematical model to first derive a relationship between road roughness, vertical human WBV, and vehicle speed. Then, using the 0.8 m/s^2 as the limit for the WBV corresponding to "uncomfortable" according to ISO 2631, they derive the following relation between "comfortable vehicle speed," cvs [km/h], and IRI [mm/m]:

$$cvs = 80 \cdot \left(\frac{IRI}{5} \right)^{\frac{2}{1-n}}$$

where n is a parameter for the amplitude of the roughness.[22] For most of the roads, the exponent n has a value around 1.8. Therefore, for a road with roughness of 6 in IRI terms, the comfortable vehicle speed should be below 50.7 km/h. At speeds above this value, the ride would be "uncomfortable" according to ISO 2631 and may have long-term health consequences to the vehicle's occupants. We use this formula to derive driving speeds in the arcs in the Colombian network according to their

[22] The value of n is low for roads where the dominating roughness amplitudes have short wavelengths, such as on a modern highway with a deteriorated surface with plenty of potholes. The value of n is high for roads where the dominating roughness amplitudes have long wavelengths, such as on an old rural low volume road (Ahlin and Granlund, 2002).

Table A.2 ■ Adjustment Factors to Road Quality

INVIAS classification	IRI range	IRI mid-point	Max speed	Percentage increase in costs
Good	(0–3)	2	Legal max speed of the road	0
Fair	(3–9)	6	50.7 km/h or legal max speed of the road whichever is less	25
Bad	(9–14)	11	11.1 km/h	25

Source: Author's calculation.

conditions. Table A.2 presents the relationship between road condition, IRI, and the resulting speeds that we use (column 4).

Adjustment of Transport Costs to Road Quality: Maintenance, Repair, Tire, and Depreciation

While lower speeds raise transport costs by increasing time in transit, road quality also raises costs for maintenance, tire, repair, and depreciation due to reduced vehicle life.[23] Barnes and Langworthy (2003) present a mathematical model for highway planning that calculates the costs of operating cars and trucks and also incorporates adjustment factors according to roadway conditions. The authors based their adjustment multipliers on available empirical assessments from various countries, including the US and New Zealand. According to the authors, the adjustment multiplier for maintenance, repair, tire, and depreciation costs for an IRI equal to or higher than 2.7 is 1.25. In other words, maintenance, repair, tire, and depreciation costs increase by 25 percent when the truck transits roads with conditions associated with an IRI equal or greater than 2.7. We take this study as a general guide on how to adjust maintenance, repair, tire, and depreciation costs in our calculations. Table A.2 (column 5) presents our findings that these costs increase by 25 percent when the road is classified as "fair" and also when the road is classified as "bad."

[23] While there is consensus in the literature that maintenance, tire, repair, and depreciation costs are affected by roadway conditions, the effect on fuel consumption is less clear. Many argue, for example, that there is no measurable difference in fuel consumption on paved roads of different roughness.

Ad Valorem Transport Costs

Once the transport costs of shipping one ton of generic merchandise are obtained for each route, we then calculate the ad valorem transport costs for each product as follows:

$$tc_{jrpt} = (TC_{rpt}) \cdot \frac{w_{jrpt}}{E_{jrpt}}$$

where tc_{jrpt} is the ad valorem transport costs of good *j* that is transported from region *r* to port *p* in year *t*, TC_{rpt} is the transport costs of shipping one ton of generic merchandise from region *r* to port *p* in year *t*, w_{jrpt} is the weight (expressed in tons) of good *j*, and E_{jrpt} is its export value.

In addition to transport costs that depend on distance, the weight to value ratio of the goods being shipped, and the conditions of the route, the ad valorem transport costs in this chapter also include the ad valorem per day time costs of exports. This is calculated by multiplying a general indicator of time sensitiveness developed by Hummels and Schaur (2007) and the time engaged in the shipment through the domestic route. These time costs are measured at an ad valorem basis. For a description of the time sensitiveness indicator, see Hummels and Schaur (2007).

Appendix B – Econometric Estimation of the Impact of Transport Costs on Trade

The empirical model is based on the following specification:

$$\ln(E_{jrpt}) = \beta_1 \cdot \ln(tc_{jrpt}) + \alpha_{jrp} + \alpha_t + \mu_{jrpt} \qquad (1.B.1)$$

where E_{jrpt} is the exports of good *j* from region *r* to port *p* in year *t*,[24] tc_{jrpt} is equal to 1+ad valorem transport costs of shipping good *j* from region *r* to port *p* in year *t*, α_{jrp} is a commodity-region-port fixed effect, a_t is a year fixed effect, and μ_{jrpt} is the error term. β_1 is the coefficient of interest. The equation is estimated separately for three groups of goods:

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[24] Port here refers to ports, airports, or borders.

Table B.1 ■ Main Econometric Results

Regressor	(1) Agriculture	(2) Mining	(3) Manufactures
Ad valorem transport costs	-7.955***	-5.999***	-7.7931***
	(0.8739)	(1.2794)	(0.2822)
Commodity-Region-Port Fixed Effect	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes
Observations	10,337	2,739	8,7512
R-sq	0.93	0.93	0.89

Source: Author's calculation

Note: The table shows OLS estimations of equation B.1 for the period 2004–2006. Robust standard errors are in parentheses ***; **; * significant at the 1%, 5%, and 10% level respectively.

agriculture, mining, and manufacturing. The product groups are defined according to the WTO classification, which in turn defines goods according to the Revision 3 of the Standard International Trade Classification (SITC). Table B.1 shows the results of the estimations.

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>> The Role of Transport Costs in Mexico's Regional Export Disparities

5

Introduction

Since the early 1940s, the spatial distribution of Mexico's economic activity, including manufacturing and foreign trade, has been heavily concentrated in a few municipalities in the country's Central East and Northeast regions, with the benefits of industrialization and integration into world markets largely bypassing the municipalities of the Northwest and South.

As extensively discussed in the literature of trade and economic geography, this dual reality seems to be rooted in an interaction between history, geography, economies of scale, and the country's trade, industrial, and infrastructure policies.

The import substitution policies of 1947–85 and the precarious development of transport infrastructure conspired to concentrate most of the country's industry around Mexico City in the Central East, as firms responded to the higher incentives to sell in the domestic market, while seeking to reap the benefits of higher economies of scale and lower transport costs when producing in the country's largest domestic market.

Then, in the mid-1980s, moves to liberalize trade and the signing of NAFTA a decade later would alter these incentives by virtually removing the anti-export bias implicit in the high levels of protection. As a result, a sizable share of manufacturing firms moved away from Mexico City and the Central East in search of the lower labor and transport costs needed to compete in export markets. However, most of the benefits of this relocation were captured by the Northeast and the Central West, to the exclusion of other areas of the country. In particular, the infrastructure-deprived South has yet to fully benefit from Mexico's increasing integration with the North American and world markets.

This chapter seeks to shed light on the role of domestic transport costs in shaping these outcomes through a detailed analysis of the impact of these costs on the regional distribution of exports. As discussed in Chapter 1, this analysis had to overcome both empirical and theoretical challenges. For the first, it proved difficult to find reliable data on transport costs from factory gates to customs. As regards the second, we were challenged by the direction of the causality: transport costs are likely to have an impact on exports from a given municipality, but the argument also runs in the other direction: scale economies arising from the volume of exports may also affect the costs of domestic transportation.

We address these challenges by building and analyzing a georeferenced, firm-level dataset that provides reliable estimates of the costs of shipping products from factory gates to customs. We use this data to estimate the impact of domestic transport costs on municipal export performance, while at least partially addressing the reverse causality issue.

Our results support the notion that domestic transport costs have been playing a significant role in the development of Mexico's regional export disparities, offsetting the advantages of lower labor and land costs in the infrastructure-deprived, peripheral regions, particularly after trade liberalization in the late 1980s and early 1990s.

A Brief History of Mexico's Regional Disparities

Mexico's industrialization took off in earnest in the late 1940s under a typical import substitution strategy marked by high import tariffs, quotas, and import licensing. This strategy, which involved costly local inputs and local prices well above the world level, forced firms to focus on the domestic market. Most chose to produce in and around Mexico City, the country's richest and most densely populated region. For the firms, it made good

Table 1 ■ GDP Regional Distribution per Economic Sector, 1985 (%)

	Region[a]				
Industrial Sector[b]	South	Central East	Central West	Northeast	Northwest
Agriculture	29.2	13.0	26.0	12.9	18.8
Mining	77.7	2.9	5.9	9.9	3.5
Manufacturing	8.0	51.7	17.7	16.8	5.7
Other Industries	18.3	40.4	17.8	14.1	9.2

Source: Data on the regional composition of sectoral GDP was obtained from INEGI.
Notes: Authors' estimates.
[a] Technical Appendix A provides a detailed description of the states included in the Northeast, Northwest, Central East, Central West, and South regions.
[b] Industrial Sectors as defined by INEGI at the one digit level of SCIAN-2007 classification.

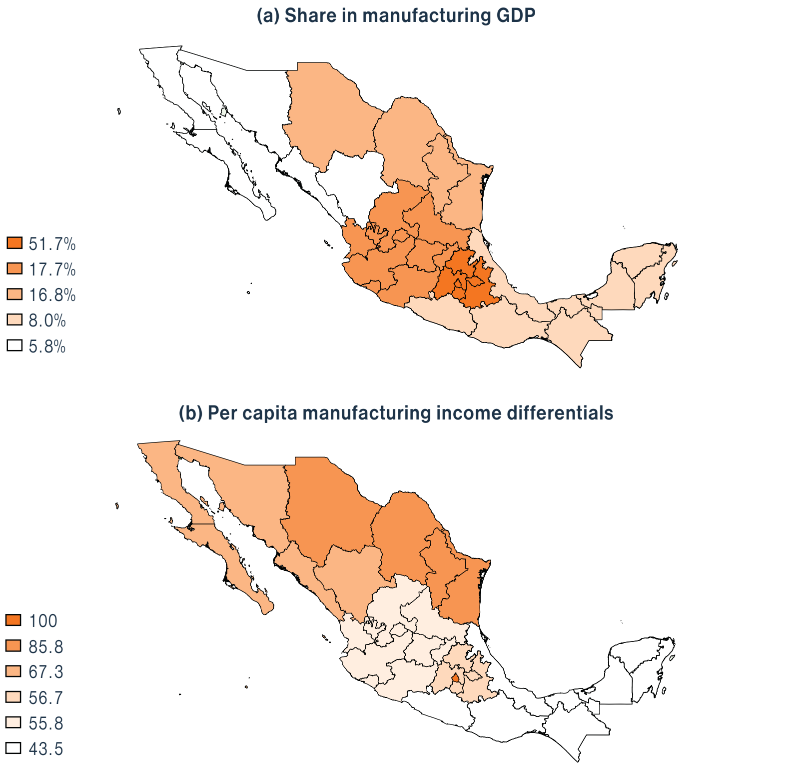
business sense to locate in the Central East, not only because of economies of agglomeration (e.g., skilled labor and suppliers) and economies of scale at the factory level, but also because of lower transport costs, a dynamics which would lead to growing regional disparities.[1]

As shown in Table 1, by 1985 nearly 52 percent of Mexico's manufacturing output was located in the Central East, a level of concentration significantly higher than for other economic activities; mining was the only exception due to the South's natural resource endowments. This rapid concentration of manufacturing activity led to growing income disparities as salaries in the Central East increased more rapidly than in the other regions (Figure 1). By 1985, average manufacturing wages in the South were just 43.5 percent of the wages in Mexico City.

Massive trade liberalization beginning in 1985 began to challenge the Central East's dominant position. When Mexico joined the North American Free Trade Agreement (NAFTA) in 1994, these challenges increased further.[2] As predicted by Krugman and Livas (1996), trade liberalization, particularly the signing of NAFTA, reduced industrial agglomeration around Mexico City as firms reacted to changes in incentives to export and to the growing competition in the domestic market.

[1] See Krugman (1991) and Krugman and Livas (1996).
[2] See Hanson (1998).

FIGURE 1 ■ Regional Manufacturing Share and per Capita Income Differentials, 1985

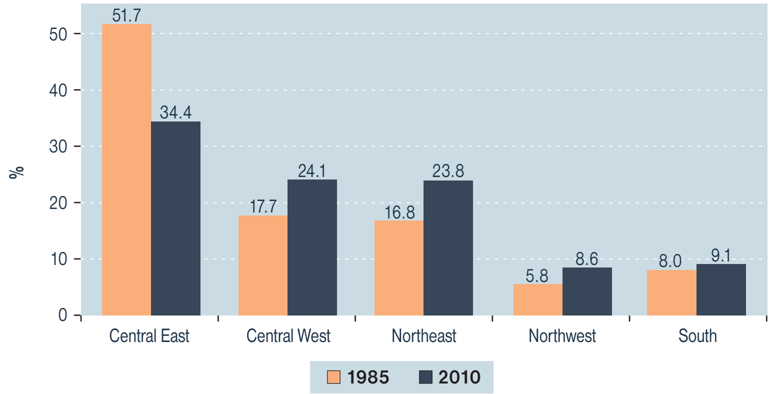


Source: Data on manufacturing GDP and population was obtained from INEGI.
Notes: Authors' estimates. Technical Appendix A provides a detailed description of the states included in the Northeast, Northwest, Central East, Central West, and South regions. Figure (b) reports the per capita manufacturing income (PCMI) differentials across regions. These differentials were calculated as follows: First, we calculate the PCMI differential for each state as the ratio of its per capita manufacturing GDP to that of Mexico City. We then calculate the weighted average of the states' ratios for each region, using the state's share of the region's manufacturing GDP as weight.

However, as shown in Figure 2, most of the benefits of this deconcentration went to the Northeast and Central West, whose shares of manufacturing GDP increased 6.4 and 7 percentage points, respectively. Meanwhile, the Central East's share of manufacturing GDP dropped by 17.3 percentage points. The South and Northwest saw only marginal gains.

Reliable long-term historical data on the regional distribution of exports does not appear to be available, but it seems reasonable to assume

FIGURE 2 ■ Changes in Regional Distribution of Manufacturing GDP, 1985–2010



Source: Data on manufacturing GDP was obtained from INEGI.
Notes: Authors' estimates. Technical Appendix A provides a detailed description of the states included in the Northeast, Northwest, Central East, Central West, and South regions.

that this distribution has been reflected by changes in the regional distribution of GDP, i.e., very high concentration in the Central East during the years of import substitution and a strong migration towards the Northeast after trade liberalization and NAFTA. This supposition is consistent with the 2010 data (shown in Figure 3), which show a spatial distribution similar to that of manufacturing GDP, but with some important nuances: a significantly higher share for the Northeast, whose nearly 35 percent share of total exports is driven by the proximity to the US market, the destination of 80 percent of Mexico's exports; and an almost negligible 2 percent share of exports for the South.[3]

This uneven pattern of deconcentration, both for manufacturing output and export levels, means that the changes driven by trade

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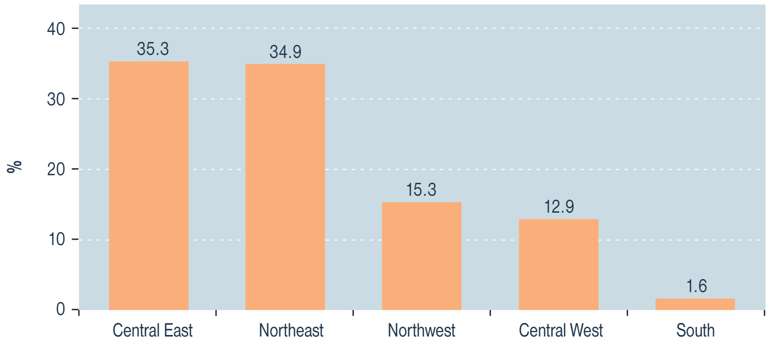
[3] Significant export disparities are also observed in the number of products exported and export destinations. The Central East exports 25 percent more products (10-digit Harmonized System) than the Central West and twice the number of products exported by the South. The Central East and the Northeast are also more diversified in terms of export destinations, exporting on average to 186 countries. That is, 20.1 percent and 46.4 percent more destinations than those exported by firms in the Central West and South, respectively.

FIGURE 3 ■ Export Share by Region, 2010



Source: Data on exports by economic region was obtained from the Ministry of Economy.
Notes: Authors' estimates. Technical Appendix A provides a detailed description of the states included in the Northeast, Northwest, Central East, Central West, and South regions. The figure above reports the regions' export share of Mexico's total export volume.

liberalization, despite its dramatic impact on the Central East, did not significantly reduce regional income disparities. In fact, some evidence suggests that those disparities might have been exacerbated. For example, a comparison of regional manufacturing income disparities in the pre- and post-liberalization periods shows all the regions falling further behind Mexico City's income levels, particularly the South (Figure 4).[4]

More rigorous estimates of per capita income convergence point to a more complex picture. For example, Figure 5 looks at the so-called beta convergence (i.e., the hypothesis that poorer regions grow faster than wealthy regions) from the pre- to post-liberalization periods. The result is in line with prior empirical evidence for a reversal in Mexico's regional per capita income convergence in the period right after trade liberalization (Chiquiar, 2005). But it also shows that this reversal was short-lived, with convergence resuming after NAFTA was signed in 1995.

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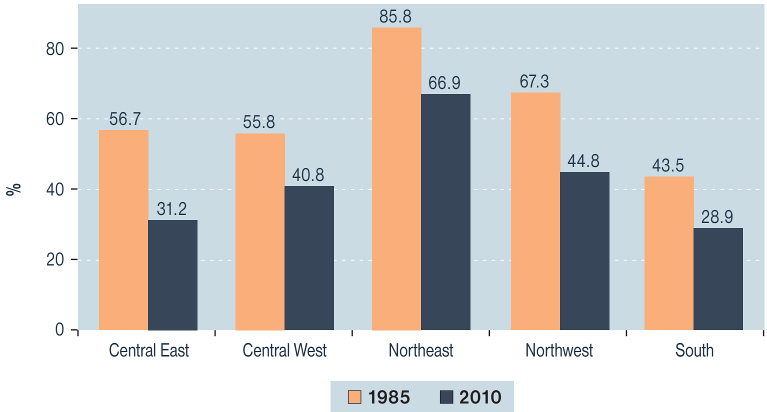
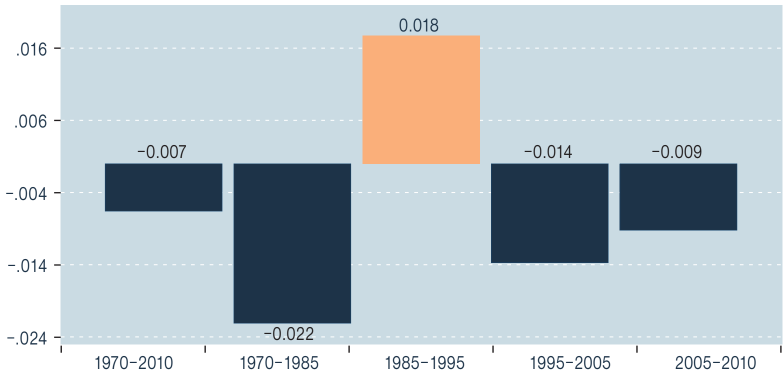
[4] It is worth noting that interregional migration did not play a significant role in reducing wage differential across regions. In fact, both the South and the Northwest increased their share of the population by 5 and 9 percent respectively during the period, whereas the Central East's share dropped by 7.6% (INEGI data).

FIGURE 4 ■ Changes in Regional per Capita Manufacturing Incomes, 1985 vs. 2010



Source: Data on manufacturing GDP and population was obtained from INEGI.
Note: Authors' estimates. Technical Appendix A provides a detailed description of the states included in the Northeast, Northwest, Central East, Central West, and South regions. The Figure reports the regions' per capita manufacturing incomes (PCMI) differentials with respect to the Federal District in 1985 and 2010, respectively. These differentials were calculated as follows: First, we calculate the PCMI differential for each state as the ratio of its per capita manufacturing GDP to that of Mexico City. We then calculate the weighted average of the states' ratios for each region, using the state's share of the region's manufacturing GDP as weight.

FIGURE 5 ■ Convergence of per Capita Manufacturing GDP Results Ex-Ante and Ex-Post the 1985 and 1994 Trade Reforms



Source: Data on manufacturing GDP was obtained from INEGI.
Note: Estimates above zero imply that per capita GDP grew at higher rates in the wealthier states (orange bar), while estimates below zero imply that per capita GDP increased at higher rates in the least developed states (blue bars). Authors' estimates. See Technical Appendix B for further details.

The current level of disparities suggests that the speed of convergence has been well below what can be expected from a trade liberalization process that has drastically reduced the incentives for firms to agglomerate in the Central East. True, the gravitational pull of the US market was likely to favor regions alongside the border, but that does not explain why the benefits were so concentrated in the Northeast and why they did not reach other border regions, such as the Northwest. Moreover, distance to the US alone cannot explain why the South exports so little, in view of its significantly lower labor costs and close proximity to Mexico's southern neighbors. As argued by Davila, Kessel, and Levy (2002), an important part of the answer may lay in the slow and regionally biased development of the transport infrastructure.

Mexico's Underlying Transport Network

As in most Latin American economies, abundant evidence suggests that the regionally biased development of the transport infrastructure in Mexico has played an important role in consolidating and deepening regional economic disparities. What makes Mexico particularly interesting and puzzling is the fact that both its colonial legacy and the policies that were followed in the early period of its independency put the country in a good position to avoid this outcome.

As elsewhere in the region, Mexico's early investments in transportation were primarily designed to connect the commodity producing areas—in this case mostly mines—to the nearest ports where the minerals would be shipped to Spain.[5] However, because of the combined effect of pre-Hispanic history (the conquest of Mexico City's based Aztec empire) and spatial distribution of mining resources, both the political and administrative capital and the country's most productive mines were located far from the coast, spread over a large area in the center and north of the country.

Those factors, in addition to the country's Pacific coastline, which provided access for occasional trade with Asia and other Spanish colonies, and the presence of a thriving US economy, led to the develop-

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[5] See, for, instance, Coatsworth (1981).

ment of a transport infrastructure that was much more extensive and regionally dispersed than, for instance, that of Brazil, the other Latin American economy comparable to Mexico in land area (See Chapter 2). This head start received a considerable boost by the rail investments during the Porfiriato period (during 1876–1911, when Mexican President Porfirio Diaz held office), which used foreign investment to construct nearly 20,000 km of railways linking Mexico City to the northern, southern, and western regions of the country.[6]

Though promising, these early developments already had key shortcomings that would be reinforced by the subsequent developments of Mexico's transport network. Among these shortcomings were the network's radial structure, with Mexico City at its center, compounded by the dearth of investments in the South and Northwest that would leave those regions poorly connected with the rest of the grid and the world markets. The radial structure would force both intra and external trade had to pass through the high altitude and congestion of the country's central regions, significantly increasing shipping costs for the peripheral regions.[7]

Mexico's radical shift to roadways, which began in the late 1920s and reached its peak in the "roads revolution" of the 1950s and 1960s, significantly integrated most of the country and created a national market.[8] Yet, despite creating a national grid of 42,000 km of paved roadways, it did not fundamentally address the shortcomings of the railway period.[9] The road grid was built following the same radial pattern as the railways, with investments heavily concentrated in the Central East and Central West regions. By 1970, the paved road density in these two regions was between two to three times higher than in the rest of country.[10]

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[6] Coatsworth op cit., p. 18. In 1911, Mexico's railway density, for instance, was 1.02 per 100 km^2 of land, nearly four times higher than that of Brazil (own calculation based on railway data from Delamadrid (2001) and IBGE (1990).

[7] Davila, Kessel, and Levy, op cit.

[8] For details of the boom see, for instance, Garcia Martinez (1992) and Fullwider (2009).

[9] Anuario Estadístico de los Estados Mexicanos (1971).

[10] The paved road densities for the Central West, Central East, Northwest, Northeast, and South were, respectively, 5.3, 5.7, 2.2, 2.9, and 2.3 km per 100 km^2 of land area. If we exclude the gulf states, which have historically benefited from the infrastructure developed for the colonial trade and oil industry, the South's density was even lower, reaching 1.6 km (Anuario Estadístico de los Estados Mexicanos, 1971).

More to the point, the road revolution did not go far enough to give Mexico a world class transport infrastructure. Indicators such as road density in the early 1970s were poor even by modest Latin American standards of the time.[11] Moreover, the focus on roadways left the railways virtually stagnated and starving for investments, despite their indisputable value for a country with continental distances. In 1970, 60 years after the end of the Porfiriato and 30 years after the railroads were nationalized, the rail grid had grown a mere 20 percent and was even more concentrated in the central regions than were the roadways. For example, the rail density in the Central East was 11 times that of the South.[12] Under these circumstances, it is no surprise that trucks became the country's dominant mode of transportation, handling 70 percent of the domestic cargo freight in the early 1970s as opposed to 24 percent for rail and just 5 percent for cabotage.[13]

The decades immediately following the roadway boom were marked by declining public investment, which reached its lows during the debt crisis of the 1980s. According to one estimate, investments in transportation by the federal government—by far the main source of funding—fell from an average of 2 percent of GDP during the boom years to 0.7 percent in the first half of 1980s.[14] The dwindling resources did not prevent the road grid from continuing to grow, but it grew at a slower pace while the government juggled competing demands for addressing maintenance and congestion at the center and developing the infrastructure in the periphery. As one analyst (Islas Rivera, 1990, p. 162) concluded, neither of these two issues ended up being satisfactorily addressed.

During the past two decades, some promising developments led to the tapping of private sector resources and management skills, though not without setbacks. The first important initiatives came with the Port Reform Law and the road concession program of 1993. The former opened the sector to competition and decentralized management, which led to more investment and higher productivity; the latter, however, suffered from design failures

[11] See Islas Rivera (1990). In 1970, Mexico's road density ranked 10th in Latin America.

[12] Anuario Estadístico de los Estados Mexicanos 1971.

[13] Islas Rivera, op. cit. Table 2.4.

[14] Islas Rivera (1990), Table 2.3.

that resulted in a government takeover four years later. The program had to wait until 2003 to be re-launched and, as of 2011, it had only 18 concessions covering 1306 km, still a tiny fraction of the country's 141,361 km of paved roadways.[15] A more decisive move took place in railways, which were almost entirely privatized in 1997 in an attempt to rescue the sector from disappearing altogether. Privatization led to significant productivity gains (OECD, 2005), but has yet to significantly boost the sector's share of domestic cargo freight, estimated at 9 percent in 2012. Nor has it led to any significant expansion of the grid.[16]

Important initiatives to boost public investments in the roads network had to wait until the early 2000s, when investments in roads are estimated to have doubled between the periods 1995–2000 and 2001–2006. This increase in public investment was complemented by a surge in private investment driven by the concessions program, which increased the overall investment in the network by a factor of three during that period.[17] The latest initiative, the 2007–2012 National Infrastructure Program, set goals for combined public and private investments in the entire transport network amounting to 4.1 percent of GDP spread over 6 years.[18]

Even though this greater level of investment marks a clear improvement over the post-boom period, it still looks modest when seen from a historical and international perspective. For instance, the government estimated that public and private investments executed in 2006–2011 represented an annual average of 0.6 percent of the country's GDP, which is less than half of what was invested during the "road boom" and roughly a third of what Chile was investing just in land transportation in the first half of the 2000s. Moreover, 70 percent of these resources were invested in roadways; clearly, no significant effort was being made to change the transport network's modal composition.[19]

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[15] SCT (2011) and Anuario Estadístico SCT (2011). See, for instance, Carpintero and Gomez-Ibanez 2011 for an analysis of the program. For an analysis of the Port Reform Law, see World Bank (2005).

[16] SCT (2011) (b).

[17] PND (2006).

[18] PNI (2007).

[19] PND (2012). The figures for Chile are from Calderon and Serven (2010).

A brief overview of the current state of Mexico's transport infrastructure also leaves no doubt that the increased investment in the last decade just began to close a gap created by decades of underinvestment, particularly in the peripheral regions and in the cheaper and more efficient transport alternatives to roadways. As of 2011, Mexico's overall road density was a mere 19 km per 100 km^2 of land area, compared to 42 in the US. Moreover, just 38 percent of Mexico's network was paved, compared to virtually 100 percent in the US. Mexico was also lagging in rail density, which was about half the US level.[20]

Perhaps more important for the purposes of this chapter is the fact that behind these averages for the country as a whole lies a deep regional disparity. The spatial distribution of Mexico's transport infrastructure remains heavily biased towards the central regions, driven by radial road and rail networks. As can be seen in Figure 6, both the current trunk road and railway networks still have the same radial structure that was the hallmark of the Porfiriato rail grid built a century ago. In addition, Figure 7 shows that these regional disparities are not declining, but rather have significantly increased in the last half a century despite the fact that some regions—such as the South—made considerable progress.[21]

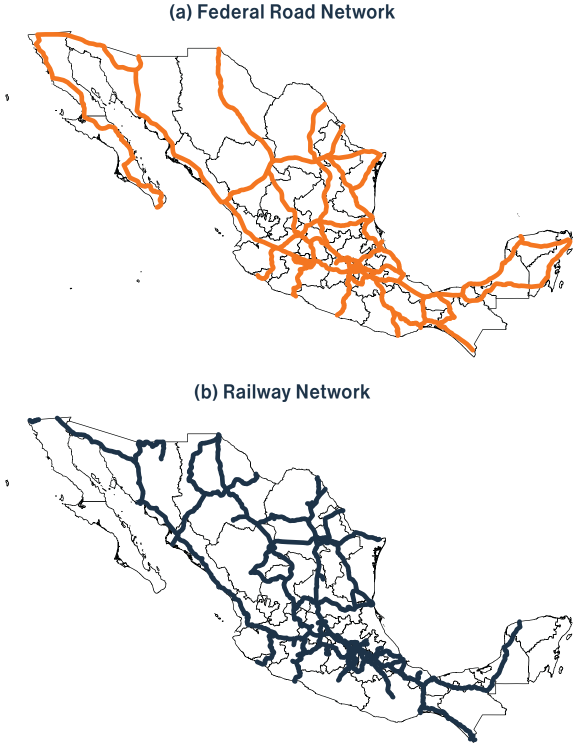
As in Brazil, as discussed in Chapter 2, this kind of protracted, modally and regionally unbalanced transport development is likely to have placed Mexico at the peak of the canonical bell curve of the economic geography literature. The curve describes a relationship between regional disparities and transport costs where disparities are low at points where trade costs are very high or very low, and reach a peak when those costs fall into an intermediate range.[22] Mexico's transport costs during the import substitution years appear not to have been high enough to prevent the formation

[20] Anuario Estadístico SCT 2011 and WDI for the US figures. Rail density in Mexico was 1.4 km compared with 2.3 in the US.

[21] The South's increase in road density is mainly driven by the states along the Gulf of Mexico and in the Yucatan peninsula, which have historically benefited from colonial links and from investments in oil and tourism. The use of alternative indicators such as road kilometers per 1000 people does not significantly alter the infrastructure disparity picture. In 2010, this indicator for the Central East was 45.9, whereas the South and the Northwest had 25.5 and 14.7, respectively (SCT, 2010 and INEGI).

[22] See, e.g., Combes, Mayer, and Thisse (2005).

FIGURE 6 ■ Mexico: Trunk Road and Railway Networks, 2011



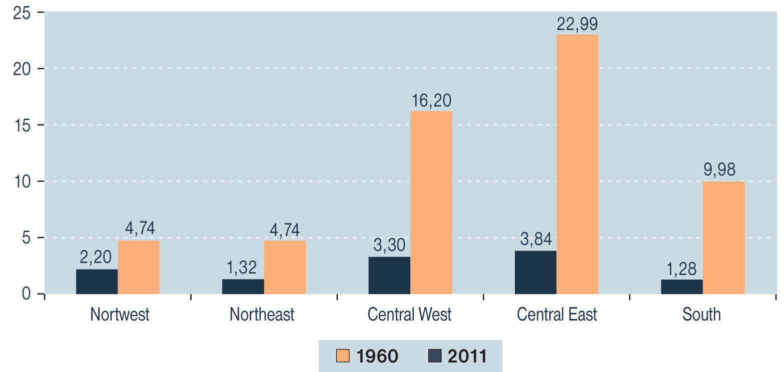
Source: GIS Data files provided by the Ministry of Communications and Transportation.

of a national market, but not low enough to prevent the economies of scale and agglomeration of the central regions from dominating the centrifugal forces of lower land and labor costs in the less developed regions.

When the economy was opened up to trade in the late 1980s, proximity to the US market probably helped the Northeast overcome the drag of its deficient infrastructure. But for regions further away from the US border, the poor and radial transport infrastructure has probably undercut any meaningful trade relationship with the US or even with Mexico's southern neighbors.

In the next section, we apply these theoretical speculations to data by using georeferenced data to estimate the direct impact of domestic transport costs on Mexican exporters.

FIGURE 7 ■ Regional Road Density in Mexico: 1960 and 2011 km² per 100 km of Land



Source: Statistical Yearbook of the Mexican States 1960-61 and SCT Statistical Yearbook 2011.

The Role of Transport Costs: An Empirical Assessment

In Mexico, as in the other countries discussed in this volume, any attempt to estimate the impact of domestic transport costs on municipal exports faces at least two major data challenges: establishing the origin (municipality) of the exports, and the cost of transporting them to the customs of exit. Firms normally list their headquarters as the source of their exports, which is not necessarily the place where they were produced, thus biasing the data towards large cities such as Mexico City. As for transport costs, the lack of data on domestic freight rates along the municipality-customs routes makes it essential to find alternative sources of information.

In addressing the origin challenge, we used a large customs transaction database provided by the Ministry of Economy that covers all exports in 2007–2010 aggregated at the municipality, product (8-digit product level of the Harmonized System), and customs level. The headquarters bias in this database was minimized by merge of the raw customs data with information from the National Statistical Directory of Economic Establishments, which lists activities and locations of all the country's firms.

For obtaining a reliable estimate of domestic transport costs, we adopted the method of Combes and Lafourcade (2005), which uses georeferenced data on operating expenses of cargo vehicles (measured in tons per kilometer) throughout the road network, which reflect time and distance-related costs determined by the length and quality of the routes. Unfortunately lack of data prevented us from including the impact of road topography on these costs, which is particularly important for the peripheral regions on the radial road grid. Likewise, there was not enough information on costs of other modal choices, such as rail or cabotage. But since roads accounted for 87 percent of all of Mexico's cargo freight in 2010, the consequences of this latter omission was minimal. The primary sources of the transport data are INEGI's Annual Survey of Transport Services and the Ministry of Communications and Transportation database on road quality.

We computed the municipality-to-customs transport costs on the least costly routes by inputting the export origin-destination and transport data into a digital version of Mexico's road network with the help of ARGIS geographical information system software. The resulting database includes 508,842 observations on the domestic transport costs of 34,374 firms exporting 6,509 goods from 902 municipalities[23] to 49 customs facilities through the least costly road routes in 2007–2010 (see Technical Appendix C).

Just by glancing at our data one can see that export concentration, which is already high at the regional level, is even higher for municipalities. Of Mexico's 2457 municipalities, only 37 percent exported in 2010, and the top ten exporters—half of them located in the two central regions, three in the Northeast, and two in the Northwest—accounted for 62 percent of the country's exports.

In addition, there are clear signs of a negative relationship between either the volume or the number of products exported by municipalities and the ad valorem cost of shipping their goods to the customs of exit (measured as percentage export prices), as shown in Figure 8.

This negative correlation between volume or number of products and transport costs also holds true at the regional level, as shown in Figure 9.

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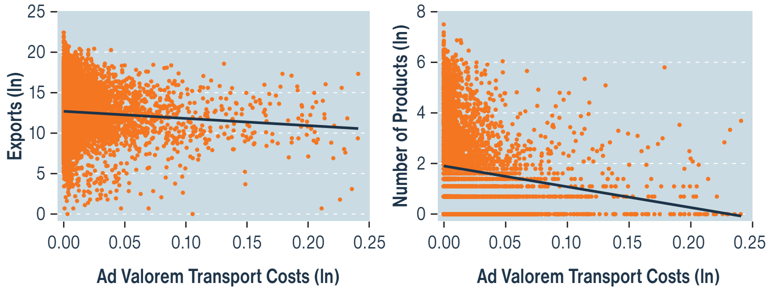
[23] Originally, the database contains information on Mexican exports from 969 municipalities. But the availability of transport cost data restricts the sample used to make estimates of the elasticity demand price. The database used in the estimates has 508,842 records containing information of export and transportation costs for products made in 902 municipalities.

FIGURE 8 ■ Total Exports and Ad Valorem Transport Costs, 2010



Source: Authors' own estimates.
Note: Exports, the total number of exported products and ad valorem transport costs are municipality-customs specific for year 2010.

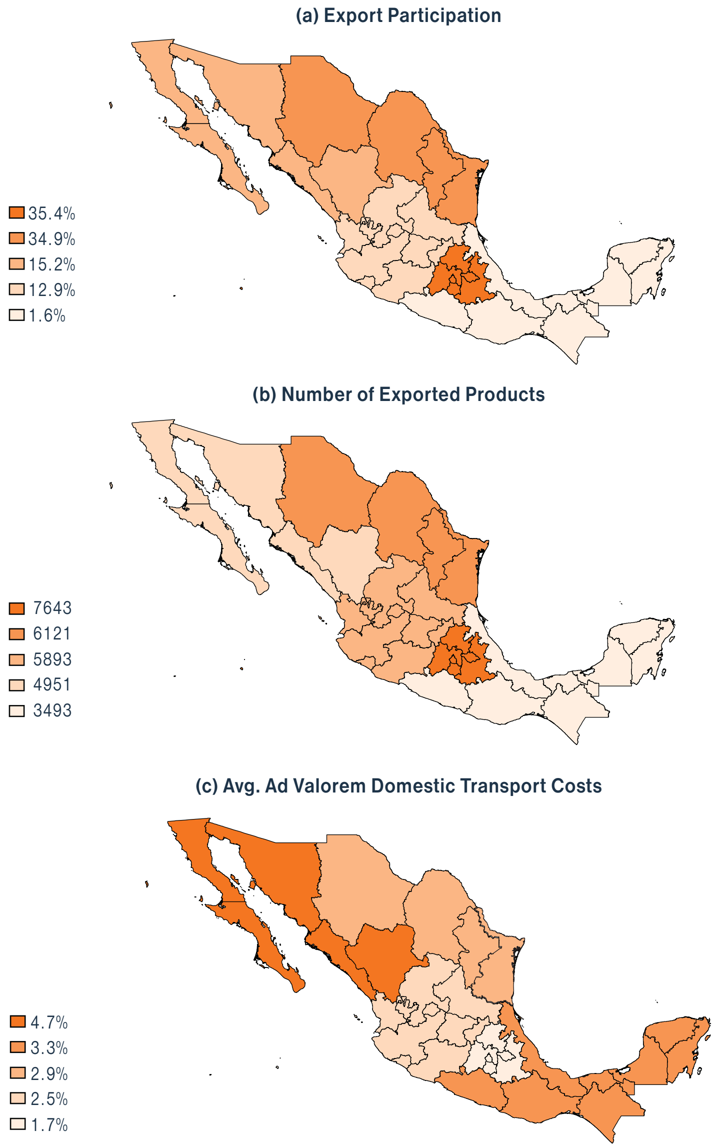
Here, the regions with the lowest export participation and fewer numbers of exported products tend to exhibit the highest ad valorem domestic transport costs. Exporters in the South, for instance, which in 2010 accounted for just 1.6 percent of the country's exports against 35.4 percent for those in the Central East, "paid" 94 percent more than their Central East counterparts to ship goods to customs.

Although suggestive, this correlation is far from conclusive since it might be driven by omitted factors that also play a role in export performance, such as comparative advantages arising from resource endowments or productivity. Moreover causality can run both ways. Higher levels of exports are likely to lower transport costs because of economies of scale in shipping and their effect on encouraging investments to improve infrastructure.

Estimating the Impact

For a more rigorous analysis of the role played by transport costs, we performed an econometric exercise capable of isolating the effects of these costs from other export determinants, and of addressing the difficult issue of causality. We therefore estimated an equation derived from trade theory that relates municipal exports at the product level with their ad valorem transport costs to the customs of exit, while controlling for characteristics

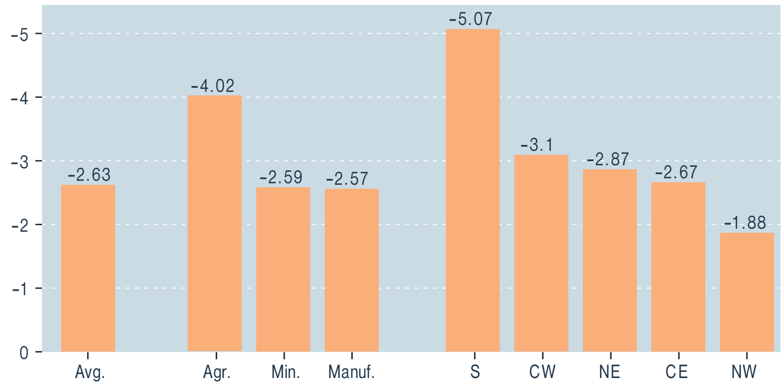
FIGURE 9 ■ Regional Export Participation and Regional Transport Costs, 2010



Source: Authors' calculations based on customs and transport costs data from the Ministry of Economy and INEGI, respectively.

Note: Figure a) reports a region's export share in year 2010. Figure b) reports the number of products exported by the municipalities located in each region. Figure c) reports a region's average ad valorem domestic transport costs in year 2010. Technical Appendix A provides a detailed description of the states included in each region.

FIGURE 10 ■ Impact of Domestic Ad Valorem Transport Costs on Exports by Municipality



Source: Author's calculations.

Note: These results are the coefficients of the ad valorem cost variable estimated using an OLS regression (equations d.7 and d.8, as derived in Technical Appendix D), having the current value of exports as the dependent variable. The average impact (Avg.) is obtained when we pool all the observations in the dataset (Table D.1 – column 7). The sectoral and regional impacts are obtained by running a different regression for each of the three product categories–agricultural (Agr.), mining (Min.), and manufacturing (Manuf.) (Table D.2 – column 7)–and for each of the five regions South (S), Central West (CW), Central East (CE), Northeast (NE), and Northwest (NW) (Table D.3 – column 7).

of the municipalities (comparative advantages and institutions), products (dimension and transportability), and customs (port specialization) that might also affect exports. Since the impact of transport costs is likely to vary significantly across products and regions, we estimated not only the average impact across all regions and products, but also the specific impact for each region and for a broad category of products, such as manufacturing, agriculture, and mining, pooling data over 2007–2010. Technical Appendix D discusses the theory and empirical strategy of these estimations in more detail.

Figure 10 summarizes the results, which confirm that transport costs have a statistically and economically significant negative impact on municipal exports.[24] On average, a 1 percent reduction in domestic ad valorem transport costs leads to a 2.6 percent increase in exports. This

[24] As reported in Technical Appendix D, all the estimated effects are significant at 1 percent. Our estimated coefficients remain significant at 1 percent even when we clustered our standard errors by sector, regions, and municipalities. Table D.4 provides a detailed report of all the results obtained when clustering standard errors.

effect is 1.6 times higher for agricultural than for manufacturing or mining products. The impact is higher in the South, the region with the lowest share of the country's exports, where a 1 percent reduction in ad valorem transport costs increases exports by as much as 5 percent. This estimated effect is 1.8 times higher than in the Center East, the region with the highest export participation in the country.

Although these estimates of impact of transport costs are revealing, they must be approached with caution because they might be biased by reverse causality, as mentioned above. That is, municipal exports might drive the lower transport costs. To try to overcome this potential bias, we ran the same regressions, but this time restricting our sample to exports originating in municipalities and shipped to customs established before the 17th, 18th, and 19th centuries. The argument is that these historic sites predate the modern influence of international trade on transport costs. The results suggest that if the bias exists, it might not be substantial since the reduced sample neither changes the sign nor significantly affects the magnitude of the impact.[25]

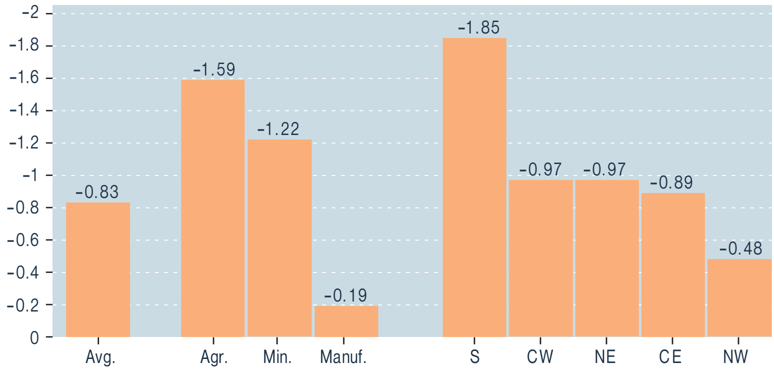
We also sought to assess the impact of transport costs on the number of exported products by a municipality (defined at the 8-digit level of the Harmonized System), the so called extensive margin of exports.[26] Figure 11 summarizes the results. On average, a 1 percent decrease in domestic ad valorem transport costs increases the municipal extensive margin of exports by 0.8 percent. The impact of lower transport costs on mining and agriculture is eight times higher than on manufacturing, and the effect across regions follows the same pattern seen with the volume of exports. The municipalities in the South benefit almost twice as much as those in the Central East.

These impacts are significantly lower than those estimated for the value of exports, suggesting that most of the gains are likely to be obtained in the intensive margin (volume) rather than in the extensive margin (diversification). This result, at least in part, reflects the fact that firms from most of the country's municipalities export a limited amount of products.

[25] See Table D.5 in the Technical Appendix.

[26] See Technical Appendix D, equations d.9 and d.10.

FIGURE 11 ■ Impact of Domestic Ad Valorem Transport Costs on the Municipal Extensive Margin of Exports



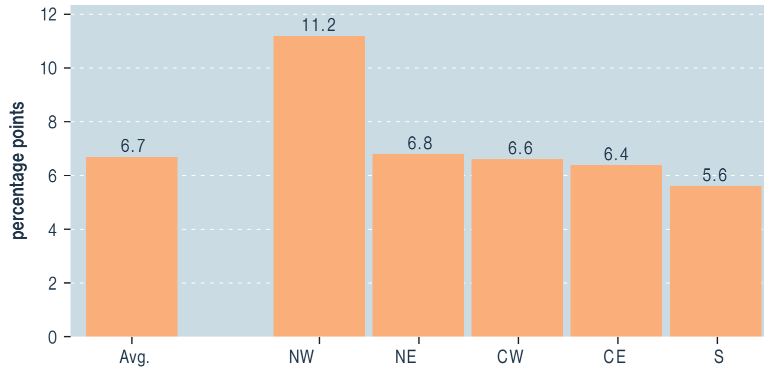
Source: Author's calculations.
Note: These results are the coefficients of the ad valorem cost variable estimated using an OLS regression (equations d.9 and d.10, as derived in Technical Appendix D), having the number of exported products (HS eight digits) as the dependent variable. The average impact (Avg.) is obtained when we pool all the observations in the dataset (Table D.6 – Panel A, column 1). The sectoral and regional impacts are obtained by running a different regression for each of the three product categories–agricultural (Agr.), mining (Min.) and manufacturing (Manuf.) (Table D.6, Panel B, column 1)–and for each of the five regions South (S), Central West (CW), Central East (CE) Northeast (NE) and Northwest (NW) (Table D.6, Panel C, column 1). Results are all significant at 1 percent.

In 2010, for instance, firms from municipalities in the South, Northwest, Northeast, Central West, and Central East, exported an average of 5, 10, 12, 9, and 14 products, respectively.

As a final exercise, we estimated the impact of transport costs on the municipalities' probability to export. A decline in transport costs is likely to not only increase the volume and the number of products a municipality exports, but also the number of municipalities that export. This effect is particularly important for a country such as Mexico where, as mentioned before, only 39 percent of the municipalities export.[27]

[27] In the context of the Melitz (2003) model of trade, a decline in ad valorem trade costs reduces the productivity threshold to export. Thus, lower productivity firms will be able to enter into exporting. In our context, this implies that a reduction in domestic ad valorem transport costs will lead to an increase in the total number of exporting municipalities. Most likely, the newly exporting municipalities are the ones located nearby the export threshold; e.g., in municipalities characterized for experiencing higher levels of domestic transport costs.

FIGURE 12 ■ Impact of Domestic Ad Valorem Transport Costs on a Municipality's Probability to Export



Source: Author's calculations.
Note: These estimates correspond to the change in the probability of entry into exporting when domestic ad valorem transport cost are reduced by 1 percent, and the marginal probability is evaluated at sample means, using the estimated coefficients of a Probit model as specified in equation d.11 and reported in Table D.3.7, column 8, of Technical Appendix D. Avg. corresponds to the estimate of pooled regression over all municipalities. CE, CW, NE, NW, and S correspond to the estimates obtained when we allow the coefficient of ad valorem transport costs to vary across regions.

Our estimates, which are based on a Probit model described in detail in Technical Appendix D, are summarized in Figure 12. They suggest a modest impact with a 1 percent reduction on domestic ad valorem transport costs, which increases the municipality's probability to export by 6.7 percentage points on a scale of 100. There is some important variance across regions, mainly in the Northwest, where the impact is significantly higher but not high enough to substantially increase the chances of its municipalities to export. At least part of the explanation for these modest figures likely comes from the fact that our ad valorem domestic transport cost variable is only measuring one component of all the factors that may determine route-specific transport costs such as the time costs related to depreciation and the financial burden of carrying stocks or the prevailing market structure of transport services.

Bringing Results Closer to Current Policies

We provide Mexico's policymakers with a further illustration of our results by applying our estimates to make a stylized assessment of the direct effect on exports of the so-called strategic core of the 2007–2012 Road Program, one of the components the 2007–2012 NIP, mentioned earlier.[28]

The strategic core covered 100 road projects that would cost approximately 1.6 percent of GDP over six years; 53 percent of the resources would be allocated to the construction of new two- and four-lane highways and the rest would increase the capacity of existing roads. As in previous initiatives, the government seemed to strive to strike a balance between alleviating congestion in the center and developing infrastructure in the peripheral regions, which is mentioned as one the program's priorities. The regional allocation of resources, though, still seems to favor the central regions, which were assigned to receive nearly 50 percent of the total, while the South, Northwest, and Northeast would receive 25.7, 12.3, and 13.1 percent, respectively.[29]

In the road program, intra-regional infrastructure projects including construction and improvements would account for at least 95 percent of the total investment in every region. In the South and the Central West more than 50 percent of the resources would finance improvements in the existing road network, while in the Northwest, Northeast, and Central East most investments targeted new road construction (Figure 13).

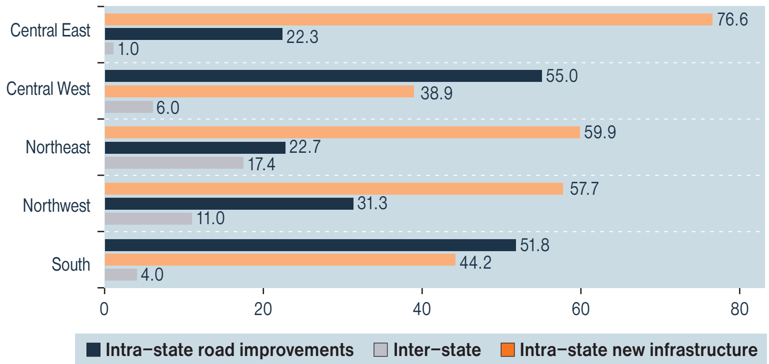
Overall, the strategic projects were supposed to cover 12,100 kilometers of roads, amounting to 8.5 percent of the paved network, 40 percent of which is located in the central regions, and 28 percent, 17 percent, and 15 percent in the South, Northwest, and Northeast, respectively. It is still not clear how much of this program was implemented; some preliminary evaluations suggest that it fell well short of its targets. The Center for the Study of Public Finance of the Mexican Congress, for instance, argues that as late as 2011, the program had completed just 41.6 percent of the projects with the most significant impacts, such as trunk roads, while exceeding its targets for rural and ancillary roads (CEFP, 2012).

Despite the program's problems in meeting its goals, for the purposes of our simulation we assume that all 100 projects were executed as planned. We

[28] SCT (2007).

[29] This allocation prompted analysts to argue that the program did not promote balanced regional development. See, e.g., Hernández Trillo (2010, p.12).

FIGURE 13 ■ Composition of the 2007–2012 Strategic Road Program by Region and Type of Investment (%)



Source: Authors' calculations based on the data from the Ministry of Communications and Transportation; only the 100 strategic projects are included.

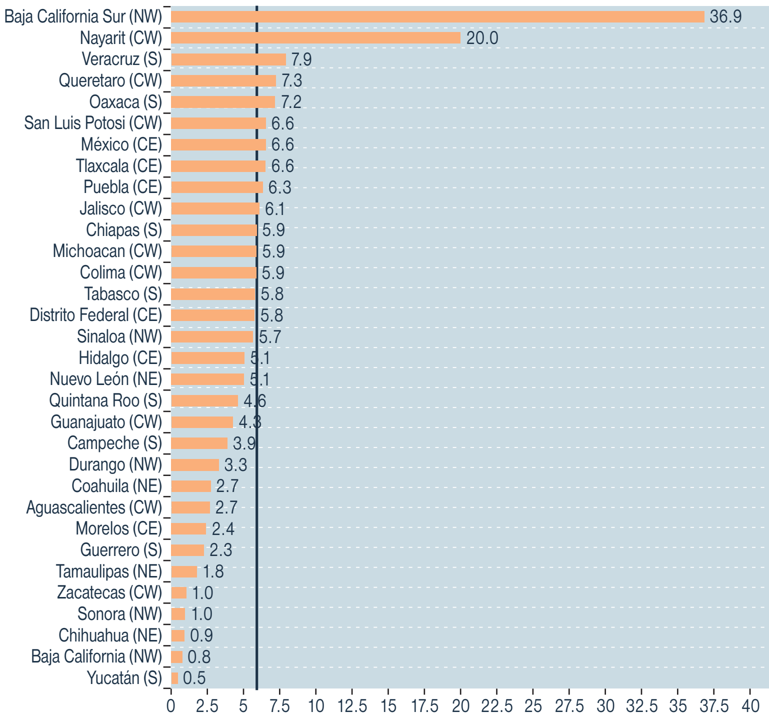
inputted their georeferenced information into our digital version of Mexico's road network to recalculate the municipality-to-customs transport costs on the least costly routes and estimate the change in transport costs (see Technical Appendix C). Panels (a) and (b) in Figure 14 show that domestic ad valorem transport costs decrease on average by 5.9 percent (blue line in panel (a)). Variations across states and regions reflect the spatial distribution of the projects. Even though the program allocation of resources does not seem to particularly target the peripheral regions, some of their states clearly appear to be among the greatest beneficiaries.

This is even more the case when we look at the impact of these lower costs on exports shown in panels (c) and (d). There, we see that exporters in the South experience the highest average increase in foreign sales (24 percent), followed by Central West exporters (20.5 percent). Big exporters such as the Central East and Northeast experience more modest gains of 14.7 percent and 7.5 percent, respectively. The impact on export diversification follows a similar pattern (panel (d)). However, as expected given the econometric estimates discussed earlier, the gains are significantly smaller across the board.

These results should probably be regarded as a lower bound of the potential gains since we are not capturing the indirect effects of lower trans-

FIGURE 14 ■ Impact of the 2007–2012 Road Program on Transport Costs, Volume, and Diversification of Exports

(a) Effect on Transport Costs



(b) Effect on Transport Costs

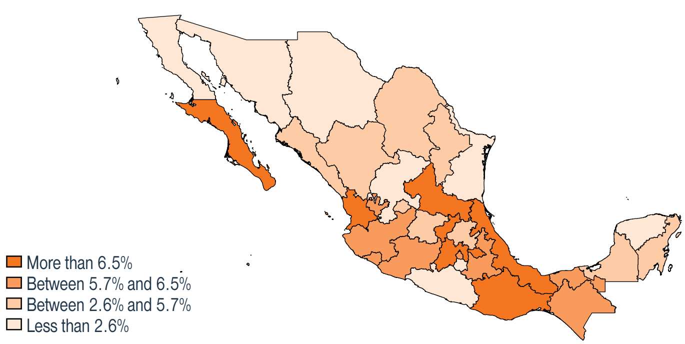


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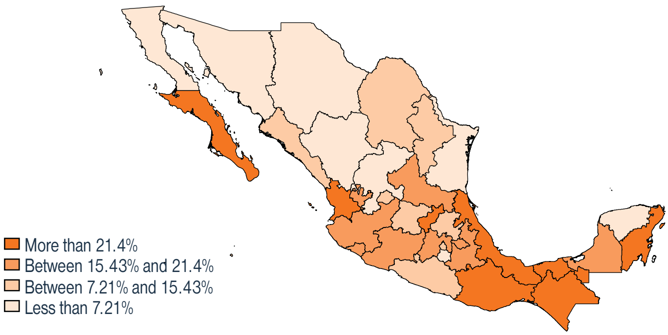
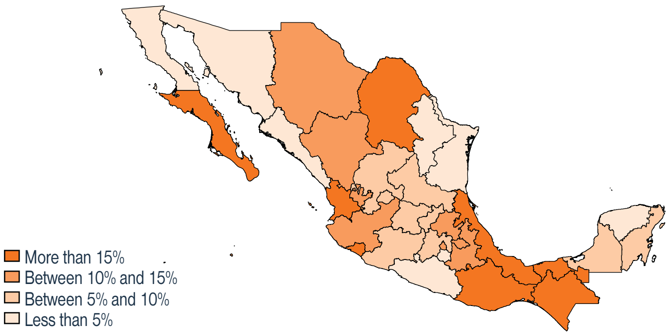
FIGURE 14 ■ Impact of the 2007–2012 Road Program on Transport Costs, Volume, and Diversification of Exports (*continued*)

(c) Total Exports



(d) Number of Exported Products



Source: Author's calculations.

Notes: Panels (a) and (b) are based on the percentage change of domestic ad valorem transport costs resulting from the implementation of the 2007–2012 Road Program's 100 strategic projects. Panel (c) results are obtained by using equation d.6 with the estimated coefficients reported in column 7 – table D.3 to predict the level of export resulting from the percentage change in domestic ad valorem transport costs as reported in panels (a) and (b). Panel (d) results are obtained by using equation d.7 with the estimated coefficients reported in column 1 – table D.6 to predict the number of exported products resulting from the percentage change in domestic ad valorem transport costs as reported in panels (a) and (b). See Technical Appendix D.

port costs on production or the gains associated with routes that minimize the negative impact of the central regions' topography. The results should also be viewed as an indication of the potential of improvements in the transport infrastructure to change a highly concentrated spatial distribution of exports; this is something that even a program that does not specifically target the less integrated regions would seem capable of achieving.

The Road Ahead

Mexico, along with Chile, has led the region in shedding import substitution policies and embracing integration into the world economy. The country clearly recognized that protectionism had not only stifled growth, but also led to deeper regional inequalities exacerbated by a radial and precarious transport infrastructure. As firms responded to protectionist incentives that discriminated against exports and enhanced the scale and transport cost advantages of being located in the center, a considerable part of the population in the peripheral regions was left behind.

With trade liberalization came the promise that integration in the world markets would not only restart growth, but also that the income gap between rich and poor regions would narrow, driven by the forces of comparative advantages. Growth did resume and a significant deconcentration of both output and exports has taken place away from Mexico City and surrounding regions. Yet, the primary beneficiary has been the Northeast, whose share of exports have grown to rival that of the central regions. The South and the Northwest have yet to see substantial gains from trade.

Why this has happened is likely due to multiple factors, not least the distribution of human capital across the country. But this chapter argues that the failure to reform and upgrade the country's transport infrastructure, whose main shortcomings were clear since the Porfiriato, is likely to have played a major role in undercutting the trade opportunities of regions far from the US border.

Although Mexican governments since the early 1990s have repeatedly given high priorities to investments in the country's unbalanced and precarious transport infrastructure, progress remains painfully slow. Mexico is still investing less than 1 percent of its GDP in the sector, a modest amount by both historical and international standards.

Our estimates show that investments to reduce transport costs would be likely to produce export returns that are both statistically and economically significant, particularly in the peripheral regions. A simulation exercise using the 2007–2012 Road Program not only illustrates this point, but also shows that even an investment program that does not focus on the infrastructure-starved regions has the potential to result in more widely distributed export benefits.

As elsewhere in the region, the key to lowering transport costs in Mexico seems to be not only to balance investments across regions, but also across modes. The 2007–2012 NIP, the latest government plan, aimed to achieve a more balanced integrated transport network. But the reality on the ground is that, despite the progress made in privatizing rail and deregulating ports, trucks remain as dominant in domestic transport as they were half a century ago. For example, although rail transportation is the cheapest transport mode for distances over 450 kilometers, its development remains constrained not only by a grid that is not much different from that built by Porfirio in the early 20th century, but also by lack of intermodal facilities in maritime ports and inland distribution centers. These problems seem to be at least partly rooted in a regulatory framework that focuses on maintenance and not expansion, and that lacks incentives for operators to share cargo across concessionaries and modes.[30]

Even in the dominant road transportation, there seems be considerable room for improvements that go beyond expanding the grid. Even though deregulation in the 1990s and early 2000s helped to promote competition and reduce costs, the ensuing atomization has been preventing costs from falling further. Smaller carriers, on average, exhibit lower levels of professionalism and formality, are less efficient, and operate an older fleet at lower economies of scale. Estimates from Instituto Mexicano para la Competitividad (2007) reveal that the average cost of cargo for firms with 1 to 5 trucks has been estimated to be 76 percent higher than for medium and large firms.

Cargo carriers would also strongly benefit if the current legislation enabled them to sell the available cargo space to third parties. This is especially important for carriers transporting cargo to the US market, as the security cargo restrictions do not allow Mexican transport

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[30] See, e.g., OECD (2005).

[31] See e.g. Instituto México para la Competitividad (IMCO) (2007).

companies to sell the available capacity to third parties. This increases transport costs as the restriction makes transport firms operate at lower economies of scale.[31]

This brief analysis does not touch on challenges faced by other transport modes, such as cabotage or air cargo. But it does demonstrate the many opportunities and strategies available to bring down Mexico's transport costs, many of which are listed in the government's plans and programs. However, in Mexico, as elsewhere in Latin America, resources and sound ideas are not always sufficient to bring about change. Equally important are strong institutions capable of planning, approving, and executing transport projects. Unfortunately, such institutions, weakened by decades of fiscal constraints, clearly pose a major stumbling block to improving the nation's transport infrastructure and reducing costs for exporters.

This point was emphatically made in a recent evaluation of the 2007–2012 Road Program carried out by an independent institution (Mexico Evalúa 2010). The evaluation cited problems quite similar to those affecting Brazil's transport programs, which were discussed in Chapter 2. Whatever actions governments undertake to bring down transport costs, addressing these institutional weaknesses should be a top priority, otherwise we will continue to see half-baked and half-implemented plans, with all the negative consequences involved.

Technical Appendix

Appendix A

FIGURE A.1 ■ Regional Classification

Source: Author's regional classification is based on Mexico's Mesoregions Classification as established in Mexico's Development Plan, 2007-2012.
Note: We classify the 32 federate states into five regions: Northwest, Northeast, Central East, Central West, and South. The Northwest is composed of Baja California (2), Baja California Sur (3), Durango (10), Sinaloa (25) and Sonora (26). The Northeast is composed of Coahuila (5), Chihuahua (8), Nuevo Leon (19) and Tamaulipas (28). The Central West is composed by Aguascalientes (1), Colima (6), Guanajuato (11), Jalisco (14), Michoacán (16), Morelos (17), Nayarit (18), Queretaro (22), San Luis Potosi (24) and Zacatecas (32). The Central East is composed by Mexico City (9), Hidalgo (13), Mexico (15), Puebla (21), and Tlaxcala (29). The South is composed by Campeche (4), Chiapas (7), Guerrero (12), Oaxaca (20), Quintana Roo (23), Tabasco (27), Veracruz (30), and Yucatan (31).

Appendix B – Convergence of Manufacturing GDP

As in Chiquiar (2005), the reported coefficients are estimated with a non-linear specification of the following reduced form:

$$\frac{\overline{y}_{i,t_o+T}-\overline{y}_{i,t_o}}{T}=\alpha-\frac{1-e^{-\beta T}}{T}\overline{y}_{i,t_o+T}+u_{i,t_o\cdot\, t_o+T} \qquad \text{(b.1)}$$

Where, $\overline{y}_{i,t_o+T}$ is the logarithm of the initial level of per capita manufacturing GDP of state i at time t_o; $\overline{y}_{i,t_o+T}$ is the logarithm of the per capita manufacturing GDP in that state i, after T years have elapsed; and

Table B.1 ■ Regional Convergence of per Capita GDP

Dependent Variable: Average Growth Rate per State	Full Sample	Sub-Periods			
	1970–2010	1970–1985	1985–1995	1995–2005	2005–2010
Constant Parameter ($\hat{\alpha}$)	0.046 (0.013)***	0.134 (0.025)***	–0.138 (0.052)**	0.101 (0.024)***	0.058 (0.033)*
Convergence Parameter ($\hat{\beta}$)	0.007 (0.003)**	0.022 (0.006)***	–0.018 (0.008)**	0.014 (0.004)***	0.009 (0.005)*
Observations	30	30	30	30	30
Adjusted R^2	0.18	0.39	0.111	0.257	0.066

$u_{i,t_o \cdot t_o+T}$ is the error term. The parameter β measures the speed of convergence towards the (common) steady state per capita output level. Under the absolute convergence hypothesis, this parameter is expected to have a positive sign. INEGI data was used to calculate manufacturing GDP per capita for the 1970–2010 period.

Table B.1 shows the β estimates for the full sample and four subs-periods used in Figure 4. For ease of interpretation, the reported results in the figure include the negative sign as implied in equation 1. Periods of convergence correspond to negative estimates (orange bars), while divergent periods correspond to the positive estimates (blue bars).

Appendix C – Exports-Transport-Costs Database

The construction of the database involved two steps: establishing the exports' origin and customs of exit and their transport costs along the minimum cost route.

Origin of exports. We resorted to a large customs transaction data-base, provide by Mexico's Ministry of Economy, covering all exports in 2007–2010. A single record in the original dataset identifies the exporting firm, the municipality, and the state where the firm is located, the product —8-digit Harmonized System code—, the customs of exit, the destination country, the value in US dollars of the transaction, the weight content of the cargo and the transport mode (air, road, railroad, and cabotage). We addressed the headquarters bias by asking the Economy Ministry to merge the original customs data with the National Statistical Directory of Economic Establishments (Directorio Estadístico Nacional de Unidades Económicas-DNUE), which covers the activity and location of all the active establishments of the country.

Transport costs. For obtaining a reliable estimate of domestic transport costs, we adopted the method of Combes and Lafourcade (2005), which uses georeferenced data on operating expenses of cargo vehicles throughout the road network, which reflect time and distance-related costs determined by the length and quality of the routes. Although the original dataset enables us to acknowledge whether the cargo was transported to a customs facility by road, air, railroad, or ocean mode, data availability on the quality of the route and the cost structure of transport companies was only available for road transportation. Hence, our estimates on the effect of domestic transport costs on municipal exports are only based on shipments using road transportation as a transport mode. The operating expenses data comes from INEGI's Annual Surveys of Transport Services for 2007–2010. Table C.1 present the summary and composition of these costs in 2010.

With the help of ARGIS geographical information system software, we inputted the export origin-destination and transport costs data into a digital version of Mexico's road network, which allowed the computation of the municipality-to-customs transport costs on the least costly cargo routes for all exports. In this setup, the total cost of each route can be described as follows:

$$T_{i,r,j,t} = [tcdist_t + (tctime_t \div vel_{i,r,j})]\, dist_{i,r,j} \tag{c.1}$$

Where $T_{i,r,j,t}$ is the total transport costs of municipality i to custom j in route r at time t; $tcdist_t$ is the distance-related cost; $tctime_t$ is the time-related cost; $vel_{i,r,j}$ is the travelling speed and $dist_{i,r,j}$ is the route's distance.

Then, the optimal domestic transport cost for an origin-destination position is:

Table C.1 ■ Determinants of Transport Costs, 2010

Panel A: Distance-Related Costs		
Components	**US$ per km per ton**	**Weight**
Fuel and lubricants	0.013	53.67
Maintenance	0.004	16.67
Materials	0.002	7.00
Other	0.005	22.67
Total	0.024	100.00
Panel B: Time-Related Costs		
Components	**US$ per hour per ton**	**Weight**
Wages	0.153	56.34
Depreciation	0.073	26.94
Taxes	0.009	3.36
Other	0.036	13.35
Total	0.271	100.00
Panel C: Total Domestic Transport Costs (US Dollars/ton)		
	US$ per km per ton	
Total distance + total time costs	0.031	

Source: Author's estimates using INEGI Annual Survey of Transport Services 2010.
Notes: Total costs is the sum of the ratio of time-related costs ($tctime_t$) to the average velocity ($vel_{r,i,j}$) plus the distance-related costs ($tcdist_t$). For this table we use 40km/h as an average reference speed. In the analysis of the chapter the speeds vary by the type of road employed.

$$T^{c}_{i,j,t} = \min\left[T_{i,1,j,t,\ldots\ldots,}T_{i,R,j,t}\right] \tag{c.2}$$

It is clear that in this framework the cost variation across routes comes from differences in distance and speed, with the latter being determined by the legal limits and conditions of the road, as defined by the database of the Road Maintenance Division of the Ministry of Communications and Transportation (*http://dgcc.sct.gob.mx/index.php?id=770*). This database contains information about the conditions of each arc in the road network defined in broad categories as "not satisfactory", "acceptable" and "good." We identify these arcs in our digital map of the network and adjust the costs of the arcs in the first two categories. The adjustment follows the same procedure as used for Colombia in Chapter 3 (see Appendix A). For the roads without information we have made the conservative assumption that they are in good condition.

Altogether, our data includes 508, 842 observations containing export and route specific transport cost data for 6,509 products (aggregated at the 8-digit level of the Harmonized System code), exported from 902 municipalities (including Mexico's 16 *delegaciones*) to 49 customs facilities between 2007–2010.

Appendix D – Empirical Specification

Our benchmark specification corresponds to an estimate of the price elasticity of demand of exports. Under the assumption of CES consumer preferences, the estimated price elasticity of demand should be greater than unit; i.e., lower than –1, implying that demand function for exported products is elastic as shown below. A representative consumer *l* located in market *j* at time *t* has preferences over two types of goods: A locally produce homogeneous good (o), and a set of differentiated imported goods (φ), defined over the continuum Ω_j. Hence, the utility function that represents its preferences is:

$$U^l_{j,t} = q^{l,\alpha}_{o,j,t}\left[\int_{\varphi\varepsilon\Omega j} q^{l,\frac{\sigma-1}{\sigma}}_{\varphi,i,j,t}\, d\varphi\right]^{\frac{\sigma-1}{\sigma}(1-\alpha)} \quad \text{(d.1)}$$

Where α is the income share allocated to the consumption of the homogeneous good, and σ is the price elasticity of demand which is elastic; i.e. $\sigma > 1$. Optimal consumption of the homogeneous and the imported goods is given are

$$q^l_{o,j,t} = \frac{\alpha I^l_{j,t}}{p_{o,j,t}} \text{and} \;\; q^l_{\varphi,i,j,t} = (1-\alpha) I^l_{j,t} \frac{p^{c-\sigma}_{\varphi,i,j,t}}{\bar{P}^{1-\sigma}_{j,t}} \qquad \forall \;\varphi \,\varepsilon\, \Omega_j. \quad \text{(d.2)}$$

$I^l_{j\,t}$ is a consumer's budget constraint, $p_{o,j,t}$ is the price of the locally produced homogeneous good, $p^c_{\varphi,i,j,t}$ is the price payed by a representative consumer located in destination *j*, for a unit of the imported variety φ at time and the price index is $\bar{P}^{1-\sigma}_{j,t} = \int_{\varphi\varepsilon\Omega j} p^{c1-\sigma}_{\varphi,i,j,t} d\varphi$

Assuming that the price of a unit of an imported product is given by the price at the factory gate in location i ($p^{s}_{\varphi,i,t}$) plus the per unit transportation cost $T^{C}_{i,j,t} \times \upsilon_{\varphi,i,t}$.; where $\upsilon_{\varphi,i,t}$ is the weight of a unit of the imported product, then it is easy to observe that the price paid by a consumer for an imported variety is

$$p^{c}_{\varphi,i,j,t} = p^{s}_{\varphi,i,t} + \left(T^{C}_{i,j,t} \times \upsilon_{\varphi,i,t}\right) = p^{s}_{\varphi,i,t}\left[1 + \frac{T^{C}_{i,j,t} \times \upsilon_{\varphi,i,t}}{p^{s}_{\varphi,i,t}}\right] \quad \forall\ \varphi\ \varepsilon\ \Omega_{j}. \quad \text{(d.3)}$$

Provided that $\frac{T^{C}_{i,j,t} \times \upsilon_{\varphi,i,t}}{p^{s}_{\varphi,i,t}} = \tau_{\varphi,i,j,t}$, equation d.3 can be re-expressed as

$$p^{c}_{\varphi,i,j,t} = p^{s}_{\varphi,i,t}\left[1 + \tau_{\varphi,i,j,t}\right] \quad \text{(d.4)}$$

Multiplying the import demand function of an imported variety (equation d.2) by the market size $L^{I}_{j,t}$ and by the price at factory gate ($p^{s}_{\varphi,i,t}$) we obtain that a variety's export value is given by,

$$p^{s}_{\varphi,i,t} q_{\varphi,i,j,t} = p^{s}_{\varphi,i,t}\left(1-\alpha\right) I^{I}_{j,t} L^{I}_{j,t} \frac{p^{c-\sigma}_{\varphi,i,j,t}}{\bar{P}^{1-\sigma}_{j,t}}. \quad \text{(d.5)}$$

Substituting equation (d.4) into (d.5) we obtain that a variety's total export value is

$$p^{s}_{\varphi,i,t} q_{\varphi,i,j,t} = \exp_{\varphi,i,j,t} = \left(1-\alpha\right) I^{I}_{j,t} L^{I}_{j,t}\left[1 + \tau_{\varphi,i,j,t}\right]^{-\sigma}\left[\frac{p^{s}_{\varphi,i,t}}{\bar{P}_{j,t}}\right]^{1-\sigma} \quad \text{(d.6)}$$

Taking logs to equation d.6, we obtain that our benchmark specification is given by:

$$ln\exp_{\varphi,i,j,t} = \beta_0 + \beta_1\ ln\left[1 + \tau_{\varphi,i,j,t}\right] + \gamma_{\varphi}\rho_{\varphi,i,j} + \theta_t \rho_t + \varepsilon_{\varphi,i,j,t} \quad \text{(d.7)}$$

$ln\exp_{\varphi,i,j,t}$ is the logarithm of the total value of exports of a variety φ, produced in municipality i, transported through route r (See equation c.2) to an exit custom-port-airport j at time t. $p_{\varphi,i,t}$ is a product-municipality-custom specific fixed effect, p_t is a year fixed effect and $\varepsilon_{\varphi,i,j,t}$ is the error term. As implied by our utility function (equation d.1), the estimate of β_1 corresponds to the price elasticity of demand for exported varieties: in this case $-\sigma$. $\hat{M}$ost important $\beta_1 < -1$ implying that the demand for exported varieties is elastic.

We extend equation (d.7) in the following two directions: First, we provide evidence of the differential effect of domestic transport costs on exports per product type; i.e., manufacturing, mining, and agricultural goods. Second, we provide evidence of the effect of domestic transport costs on the total value of exports per economic region. As provided in Table 1-Appendix A, we classified México's 32 states into five mesoregions: Northeast, Northwest, Central East, Central West, and South. In both cases estimates are performed using the following reduced form:

$$ln\exp_{\varphi,i,j,t} = \beta_0 + \sum_{z=1}^{z} \beta_z \; ln\left[1+\tau_{\varphi,i,j,t}\right] + \sum_{z=1}^{z} \alpha_z \rho_z + \gamma_\varphi \rho_{\varphi,i,j} + \theta_t \rho_t + \varepsilon_{\varphi,i,j,t} \qquad (d.8)$$

Sub-index z identifies the sector or the export region. ρ_z is a fixed effect related to the region or to the product groups.

We now turn to the effect of domestic ad valorem transport costs on a Municipality's Extensive Margin of exports. A municipality's extensive margin of exports is measured by the count of exported products. For robustness purposes we count the number of exported products at two disaggregation levels of the Harmonized System code: 6 and 8. The effect of domestic ad valorem transport costs on the extensive margin of exports a municipality is given by the following reduced form:

$$lnN_{i,t} = \beta_0 + \beta \ln\left[1+\tau_{i,t}^{med}\right] + \theta_i \rho_i + \gamma_i \rho_i + \varepsilon_{i,t} \qquad (d.9)$$

$N_{i,s,t}$ corresponds to the number of products exported by municipality i at time t. $\tau_{i,t}^{med}$ is the median ad valorem domestic transport cost when shipping from municipality i. ρ_i controls for non-observable municipality specific factors affecting the extensive margin, while ρ_t controls for non-observable year specific factors affecting all municipality's in a similar way. As in equation (d.8), we provide evidence of the differential effect of domestic ad valorem transport costs by product type and by export region. In these two cases, our reduced form is then extended as follows:

$$lnN_{i,t} = \beta_0 + \sum_{z=1}^{z} \beta_z \; ln\left[1 + \tau_{i,t}^{med}\right] + \theta_i \rho_i + \theta_t \rho_t + \varepsilon_{i,t} \qquad \text{(d.10)}$$

Last but not least, we analyze the effect of domestic ad valorem transport costs on a municipality's entry into exporting. We estimate the following reduced form:

$$id\exp_{i,s,t} = \beta_0 + \beta \ln\left[1 + \tau_{i,s,t}^{med}\right] + \theta_s \rho_s + \varepsilon_{i,s,t} \qquad \text{(d.11)}$$

$id\exp_{i,s,t}$ is a dichotomic variable taking the value of one when a municipality is located in state exports to a foreign destination at time *t*, and zero otherwise. $\tau_{i,s,t}^{med}$ is the median ad valorem domestic transport cost when shipping from a municipality *i* located in state *s*. For the years when a municipality does not export we replace the non-obserable ad valorem transport cost for the maximum value of the state's where the municipality is geographically located. The reason to make this replacement relies on the concept that when a municipality does not export, one of the reasons is because the cost of transportation is too big; which in our case corresponds to the maximum value. Non-reported robustness checks included estimates when the domestic ad valorem transport costs were replaced with the state's value evaluated at the median, 90^{th} and 95^{th} percentile. In all these case results are similar in magnitude and significance to the ones reported in this chapter.

We estimated equation d.11 using first a linear probability model, and then a probit model. These estimates are then extended to provide evidence of the asymmetric effect domestic ad valorem transport costs on entry into exporting across export regions.

Table D.1 ■ Impact of Transport Costs on Municipal Exports per Product

Dependent Variable: Ln. Value of Exports (fob)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ad Valorem Transport Cost	−2.667 (0.155)***	−2.665 (0.156)***	−2.65 (0.155)***	−2.647 (0.156)***	−2.643 (0.159)***	−2.627 (0.159)***	−2.627 (0.159)***
Municipality-Customs-Product Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	No	No	No	No	No	No
Customs-Year Fixed Effects	No	Yes	No	Yes	Yes	No	Yes
Municipality-Year Fixed Effects	No	No	Yes	Yes	No	Yes	Yes
Product-Year Fixed Effects	No	No	No	No	Yes	Yes	Yes
Observations	508,841	508,841	508,841	508,841	508,841	508,841	508,841

Source: Authors' estimates.

Note: t: 2007–2010. Export data obtained from the customs level data provided by Secretaría de Economía de México. Transport Costs per unit of weight were calculated as explained in Appendix C. Domestic ad valorem transport costs correspond to ln[1+ $t_{\phi,i,j,t}$]. $t_{\phi,i,j,t}$ is calculated as derived in equation d.4. Column (1) corresponds to the benchmark specification derived in equation d.5. Column (2)–(7) are extensions that include non-observable factors that may have biased our estimates for β_1.

Table D.2 ■ Impact of Transport Costs on Municipal Exports by Product Category

Dependent Variable: Ln. Value of Exports (fob)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ad Valorem Transport Costs: Agriculture	−4.053 (0.546)***	−4.083 (0.546)***	−4.037 (0.539)***	−4.088 (0.537)***	−4.037 (0.540)***	−3.991 (0.527)***	−4.025 (0.522)***
Ad Valorem Transport Costs: Mining	−2.542 (0.417)***	−2.564 (0.412)***	−2.518 (0.430)***	−2.507 (0.418)***	−2.602 (0.420)***	−2.602 (0.436)***	−2.589 (0.419)***
Ad Valorem Transport Costs: Manufacturing	−2.607 (0.163)***	−2.602 (0.164)***	−2.592 (0.163)***	−2.587 (0.164)***	−2.582 (0.167)***	−2.568 (0.166)***	−2.567 (0.167)***
Municipality-Customs-Product Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	No	No	No	No	No	No
Customs-Year Fixed Effects	No	Yes	No	Yes	Yes	No	Yes
Municipality-Year Fixed Effects	No	No	Yes	Yes	No	Yes	Yes
Product-Year Fixed Effects	No	No	No	No	Yes	Yes	Yes
Observations	508,841	508,841	508,841	508,841	508,841	508,841	508,841

Source: Authors' estimates.

Note: t: 2007–2010. Export data obtained from the customs level data provided by Secretaría de Economía de México. Transport Costs per unit of weight were calculated as explained in Appendix C. Domestic ad valorem transport costs correspond to ln[1+ $t_{\phi,i,j,t}$]. $t_{\phi,i,j,t}$ is calculated as derived in equation d.4. Column (1) corresponds to the benchmark specification derived in equation d.6. Column (2)–(7) are extensions that include non-observable factors that may have biased our estimates for β_1.

Table D.3 ■ Impact of Transport Costs on Municipal Exports by Region

Dependent Variable: Ln. Value of Exports (fob)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ad Valorem Transport Costs: Central East	−2.677 (0.308)***	−2.681 (0.311)***	−2.674 (0.312)***	−2.669 (0.314)***	−2.675 (0.318)***	−2.676 (0.321)***	−2.671 (0.323)***
Ad Valorem Transport Costs: Central West	−3.139 (0.402)***	−3.137 (0.403)***	−3.09 (0.400)***	−3.089 (0.400)***	−3.144 (0.414)***	−3.099 (0.411)***	−3.098 (0.411)***
Ad Valorem Transport Costs: Northeast	−2.904 (0.316)***	−2.898 (0.315)***	−2.914 (0.319)***	−2.911 (0.316)***	−2.859 (0.322)***	−2.871 (0.327)***	−2.871 (0.323)***
Ad Valorem Transport Costs: Northwest	−1.968 (0.213)***	−1.962 (0.213)***	−1.914 (0.201)***	−1.911 (0.203)***	−1.93 (0.217)***	−1.867 (0.205)***	−1.876 (0.206)***
Ad Valorem Transport Costs: South	−4.62 (1.269)***	−4.644 (1.283)***	−5.062 (1.264)***	−5.061 (1.265)***	−4.667 (1.217)***	−5.037 (1.186)***	−5.071 (1.194)***
Municipality-Customs-Product Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	No	No	No	No	No	No
Customs-Year Fixed Effects	No	Yes	No	Yes	Yes	No	Yes
Municipality-Year Fixed Effects	No	No	Yes	Yes	No	Yes	Yes
Product-Year Fixed Effects	No	No	No	No	Yes	Yes	Yes
Observations	508,841	508,841	508,841	508,841	508,841	508,841	508,841

Source: Authors' estimates.

Note: t: 2007–2010. Export data obtained from the customs level data provided by Secretaría de Economía de México. Transport Costs per unit of weight were calculated as explained in Appendix C. Domestic ad valorem transport costs correspond to ln[1+ $t_{\phi,i,j,t}$]. $t_{\phi,i,j,t}$ is calculated as derived in equation d.4. Column (1) corresponds to the benchmark specification derived in equation d.6.Column (2)–(7) are extensions that include non-observable factors that may have biased our estimates for β_1.

Table D.4 ■ The Impact of Transport Costs on Municipal Exports per Product, Alternate Standard Errors

Dependent Variable: Ln. Value of Exports (fob)	All Sample (1)	Sector Classification: Agr. (2)	Mining. (3)	Manuf. (4)	Regional Classification: CE (5)	CW (6)	NE (7)	NW (8)	S (9)
Ad Valorem Transport Cost	−2.667	−4.053	−2.542	−2.607	−2.677	−3.139	−2.904	−1.968	−4.62
Clustered by Municipality-Customs-Product	(0.155)***	(0.546)***	(0.417)***	(0.163)***	(0.308)***	(0.402)***	(0.316)***	(0.213)***	(1.269)***
Clustered by Sector, 5-Digit SITC	(0.262)***	(0.771)***	(0.436)***	(0.265)***	(0.299)***	(0.406)***	(0.699)***	(0.271)***	(1.310)***
Clustered by Sector, 4-Digit México SCIAN	(0.241)***	(0.883)***	(0.666)***	(0.230)***	(0.358)***	(0.354)***	(0.585)***	(0.153)***	(1.418)***
Clustered by Sector, 3-Digit México SCIAN	(0.257)***	(0.975)***	(0.516)***	(0.244)***	(0.400)***	(0.363)***	(0.570)***	(0.144)***	(1.117)***
Clustered by Municipality	(0.216)***	(0.531)***	(0.577)***	(0.228)***	(0.369)***	(0.429)***	(0.426)***	(0.248)***	(1.298)***
Clustered by State	(0.261)***	(0.512)***	(0.619)***	(0.277)***	(0.464)***	(0.322)***	(0.346)***	(0.245)***	(0.870)***
Clustered by Municipality-Sector, 5-Digit SITC	(0.164)***	(0.565)***	(0.425)***	(0.172)***	(0.325)***	(0.417)***	(0.366)***	(0.206)***	(1.302)***
Clustered by Municipality-Sector, 4-México SCIAN	(0.166)***	(0.599)***	(0.484)***	(0.173)***	(0.334)***	(0.406)***	(0.372)***	(0.201)***	(1.333)***
Clustered by Municipality-Sector, 3-México SCIAN	(0.168)***	(0.597)***	(0.487)***	(0.176)***	(0.330)***	(0.403)***	(0.383)***	(0.210)***	(1.345)***
Clustered by State-Sector, 5-Digit SITC	(0.167)***	(0.590)***	(0.424)***	(0.174)***	(0.283)***	(0.420)***	(0.418)***	(0.219)***	(1.300)***
Clustered by State-Sector, 4-México SCIAN	(0.170)***	(0.642)***	(0.506)***	(0.177)***	(0.306)***	(0.409)***	(0.402)***	(0.202)***	(1.471)***
Clustered by State-Sector, 3-México SCIAN	(0.182)***	(0.598)***	(0.527)***	(0.192)***	(0.344)***	(0.437)***	(0.408)***	(0.207)***	(1.291)***
Observations	508,842	508,842	508,842	508,842	508,842	508,842	508,842	508,842	508,842

Source: Authors' estimates.

Note: t: 2007–2010. Export data obtained from the customs level data provided by Secretaría de Economía de México. Transport Costs per unit of weight were calculated as explained in Appendix C. Domestic ad valorem transport costs correspond to ln[1+ $t_{\phi,i,j,t}$]. $t_{\phi,i,j,t}$ is calculated as derived in equation d.4. Column (1) corresponds to the benchmark specification derived in equation d.5. Column (2)–(4) and (5)–(9) correspond to the estimates across products and export regions as defined in equation d.6. The different rows of standard errors correspond to estimates performed by allowing different forms of clustering.

Table D.5 ■ The Impact of Transport Costs on Municipal Exports per Product, Historical Sample

Panel A: Impact of Transport Costs on Municipal Exports			
	Historic Sample		
Dependent Variable: Ln. Value of Exports (fob)	**1600's**	**1700's**	**1800's**
Ad Valorem Transport Cost	−2.982 (0.358)***	−2.795 (0.290)***	−2.654 (0.246)***
Municipality-Customs-Product Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	No	No	No
Customs-Year Fixed Effects	Yes	Yes	Yes
Municipality-Year Fixed Effects	Yes	Yes	Yes
Product-Year Fixed Effects	Yes	Yes	Yes
Observations	150,193	174,960	197,468
Panel B: Impact of Transport Costs on Municipal Exports, across sectors			
	Historic Sample		
Dependent Variable: Ln. Value of Exports (fob)	**1600's**	**1700's**	**1800's**
Ad Valorem Transport Costs: Agriculture	−4.053 (0.546)***	−4.083 (0.546)***	−4.037 (0.539)***
Ad Valorem Transport Costs: Mining	−2.542 (0.417)***	−2.564 (0.412)***	−2.518 (0.430)***
Ad Valorem Transport Costs: Manufacturing	−2.607 (0.163)***	−2.602 (0.164)***	−2.592 (0.163)***
Municipality-Customs-Product Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	No	No
Customs-Year Fixed Effects	No	Yes	No
Municipality-Year Fixed Effects	No	No	Yes
Product-Year Fixed Effects	No	No	No
Observations	508,841	508,841	508,841

Continued on next page

Table D.5 ■ The Impact of Transport Costs on Municipal Exports per Product, Historical Sample *(continued)*

Panel C: Impact of Transport Costs on Municipal Exports, across mesoregions			
Dependent Variable: Ln. Value of Exports (fob)	Historic Sample		
	1600's	1700's	1800's
Ad Valorem Transport Costs: Central East	−1.784 (0.417)***	−1.808 (0.417)***	−1.813 (0.417)***
Ad Valorem Transport Costs: Central West	−3.955 (0.472)***	−3.903 (0.489)***	−3.853 (0.487)***
Ad Valorem Transport Costs: Northeast	−2.995 (0.734)***	−3.188 (0.569)***	−2.673 (0.379)***
Ad Valorem Transport Costs: Northwest	−2.371 (0.530)***	−1.483 (0.389)***	−1.575 (0.384)***
Ad Valorem Transport Costs: South	−5.934 (3.139)*	−5.869 (2.935)**	−5.718 (2.937)*
Municipality-Customs-Product Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	No	No	No
Customs-Year Fixed Effects	Yes	Yes	Yes
Municipality-Year Fixed Effects	Yes	Yes	Yes
Product-Year Fixed Effects	Yes	Yes	Yes
Observations	508,841	508,841	508,841

Source: Authors' estimates.

Note: t: 2007–2010. Export data obtained from the customs level data provided by Secretaría de Economía de México. Transport Costs per unit of weight were calculated as explained in Appendix C. Domestic ad valorem transport costs correspond to ln[1+ $t_{\phi,i,j,t}$]. $t_{\phi,i,j,t}$ is calculated as derived in equation d.4. Column (1) corresponds to the estimates obtained when we only include exports from the municipalities created before the 1600s. Column (2) corresponds to the estimates obtained when we only include exports from the municipalities created before the 1700s. Column (3) corresponds to the estimates obtained when we only include exports from the municipalities created before the 1800s. Panel A corresponds to the estimates of the benchmark specification derived in equation d.5. Panels B and C correspond to the estimates across products and export regions as derived in equation d.6.

Table D.6 ■ The Impact of Transport Costs on Muncipal Exports, Extensive Margin

Panel A: All Products, All Regions		
Dependent Variable: Ln. Number of Products	**Product Classifications**	
	HS8	**HS6**
Ad Valorem Transport Costs	−0.828 (0.131)***	−0.806 (0.128)***
Panel B: Product Type		
Dependent Variable: Ln. Number of Products	**Product Classifications**	
	HS8	**HS6**
Ad Valorem Transport Costs: Agricultural Products	−1.223 (0.297)***	−1.200 (0.292)***
Ad Valorem Tranposrt Cost: Mining Products	−1.589 (0.203)***	−1.56 (0.200)***
Ad Valorem Transport Cost: Manufacturing Products	−0.190 (0.082)**	−0.173 (0.080)**
Panel C: Mesoregion Classification		
Dependent Variable: Ln. Number of Products	**Product Classifications**	
	HS8	**HS6**
Ad Valorem Tranposrt Cost: Central East	−0.972 (0.284)***	−0.95 (0.279)***
Ad Valorem Transport Cost: Central West	−0.890 (0.258)***	−0.868 (0.252)***
Ad Valorem Transport Cost: Northeast	−0.972 (0.312)***	−0.941 (0.304)***
Ad Valorem Transport Cost: Northwest	−0.476 (0.142)***	−0.455 (0.137)***
Observations	27,421	27,421

Source: Authors' estimates.

Note: t: 2007–2010. Export data obtained from the customs level data provided by Secretaría de Economía de México. Transport Costs per unit of weight were calculated as explained in Appendix C. Domestic ad valorem transport costs correspond to ln[1+ $t_{i,t}^{med}$]. $t_{i,t}^{med}$ is calculated as derived in equation d.7. Panels B and C report the estimates obtained when extending the benchmark results as given by equation d.8. In column (1) a municpality's extensive margin of exports corresponds to number of exported products at the 8 digit level of the Harmonized System code. In column (2) a municipality's extensive margin of exports corresponds to the number of exported products at the 6-digit level of the harmonized system code. All estimates control for municipality and year fixed effects.

Table D.7 ■ Impact of Transport Costs on Municipal Export Entry

Panel A: Overall Effect								
Dependent Variable:	Linear Probability				Probit			
Municipal Entry into Exporting	Average	Median	Max	Weighted	Average	Median	Max	Weighted
Transport Cost	−0.077 (0.008)***	−0.08 (0.008)***	−0.077 (0.008)***	−0.076 (0.006)***	−0.205 (0.022)***	−0.216 (0.022)***	−0.206 (0.022)***	−0.208 (0.018)***

Panel B: Regional Effect								
Dependent Variable:	Linear Probability				Probit			
Municipal Entry into Exporting	Average	Median	Max	Weighted	Average	Median	Max	Weighted
Transport Cost: Central East	−0.086 (0.016)***	−0.088 (0.016)***	−0.086 (0.016)***	−0.076 (0.012)***	−0.214 (0.045)***	−0.221 (0.046)***	−0.213 (0.045)***	−0.200 (0.036)***
Transport Cost: Central West	−0.072 (0.011)***	−0.074 (0.011)***	−0.072 (0.011)***	−0.07 (0.009)***	−0.206 (0.036)***	−0.213 (0.036)***	−0.205 (0.037)***	−0.205 (0.032)***
Transport Cost: Northeast	−0.06 (0.017)***	−0.057 (0.017)***	−0.071 (0.018)***	−0.065 (0.011)***	−0.168 (0.047)***	−0.162 (0.047)***	−1.98 (0.049)***	−0.212 (0.038)***
Transport Cost: Northwest	−0.117 (0.023)***	−0.115 (0.022)***	−0.109 (0.023)***	−0.118 (0.016)***	−0.324 (0.078)***	−0.319 (0.077)***	−2.97 (0.076)***	−0.346 (0.070)***
Transport Cost: South	−0.06 (0.020)***	−0.073 (0.019)***	−0.061 (0.019)***	−0.070 (0.014)***	−0.163 (0.051)***	−1.99 (0.050)***	−1.67 (0.050)***	−1.73 (0.038)***
Observations	9,633	9,633	9,633	9,633	9,633	9,633	9,633	9,633

Source: Authors' estimates.

Note: t:2007–2010. Export data obtained from the customs level data provided by Secretaría de Economía de México. Transport Costs per unit of weight were calculated as explained in appendix C. The independent variables that refer to the domestic transport correspond to $t_{i,t}^{med}$ which is calculated as as derived in equation d.9. Panel A corresponds to the estimates under the benchmark specification–equation d.9. Panel B reports the estimates obtained when extending the benchmark results across export regions. In columns (1)–(4) we report the results obtained under a linear probability model. In columns (5)–(8) we report the results obtained under a probit estimation. In columns (1)–(3) transport costs by municipality were estimated as the average, median, and max transport costs, respectively, of all the routes through which the municipality exports. In column (4), transport cost by municipality were estimated by adding up the weighted transport costs of all the routes through which the municipality exports (the transport cost per route was weighted by the share of exports of each route in the total exports of the municipality). All results include state and year fixed effects.

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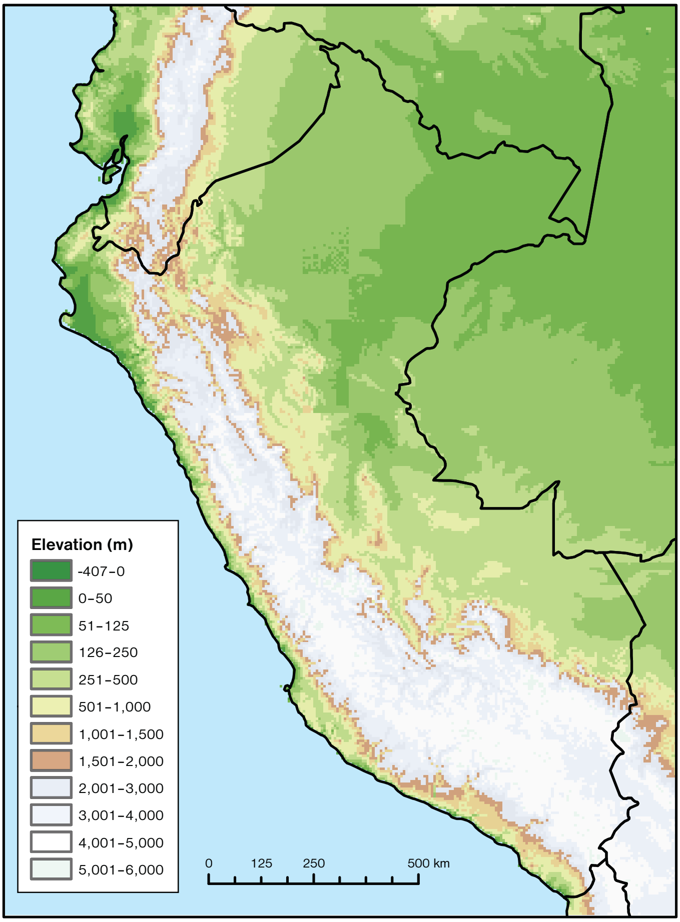
>> Peru: Road Infrastructure and Regional Exports with a Challenging Geography 6

A land of enormous natural diversity, Peru contains 84 of the world's 104 ecological regions (see Escobal and Torero, 2000). Peru is also a land of extremes. Its coastal region (the *Costa*) is one of the driest places on earth, with precipitation averaging less than 60 mm (millimeters) per year. In contrast, the Amazon region (the *Selva*) receives on average more than 2,000 mm of rain annually, which causes periodic floods that inundate thousands of square kilometers of land. In between lies the Andean region (the *Sierra*), where the average temperature of 12.5°C is half that of the other regions and whose mountains of up to 6,768 meters above sea level (Nevado Huascarán) form a natural barrier to movements of goods and people (see Escobal and Torero, 2000 and MD, 2005). Median altitudes range from less than 500 meters above sea level on the Costa and Selva, to more than 3,000 meters in the Sierra, which makes Peru the world's third "roughest" country in terms of topographic variability. Only China and Nepal score higher (see Ramcharan, 2009) (see Figures 1 and 2).

Peru's climate presents serious challenges to transportation networks. The frequent occurrence of extremely high temperatures can deteriorate pavement and cause rutting, which increases construction and maintenance costs (see ICF International, 2010). Heavy rains may lead to complete suspension of highway construction due to saturated and unworkable

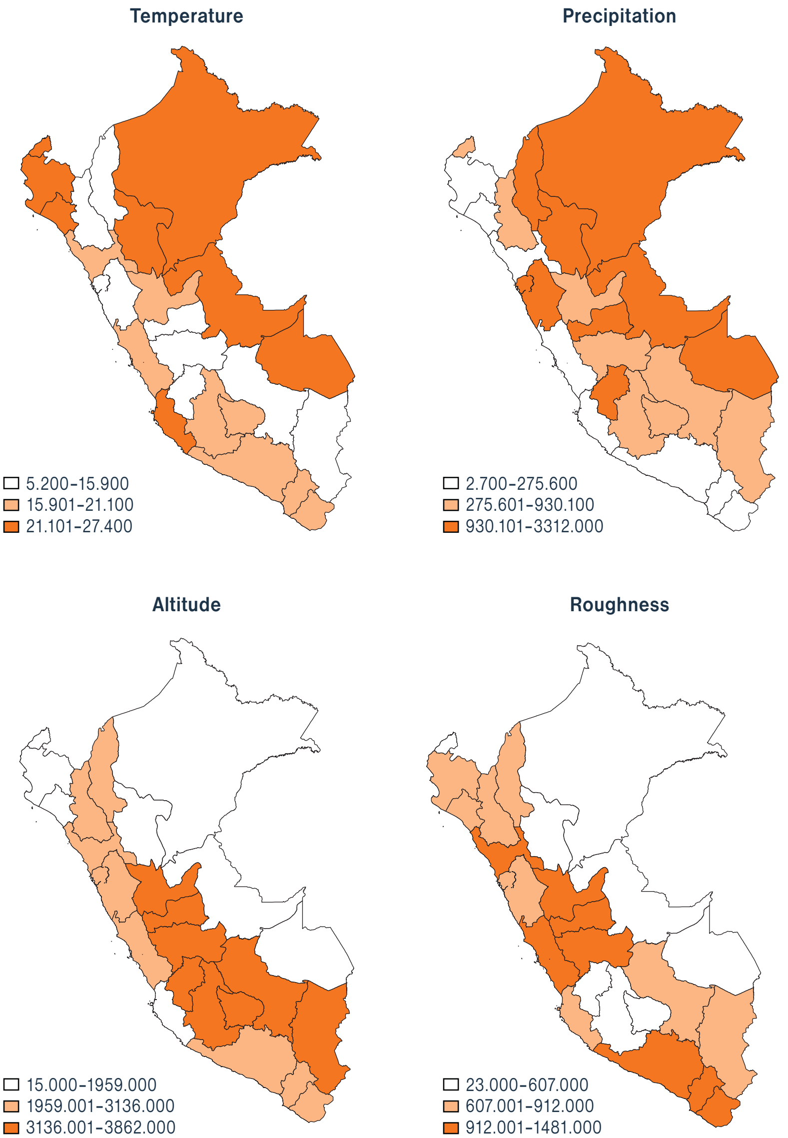
FIGURE 1 ■ Elevation Map



Source: ArcGIS.

soil conditions and the complete closing of roads due to flooding and erosion (see El-Rayes and Moselhi, 2001; Ministry of Transportation and Communications-MTC, 2005). Also important for Peru, roughness can make it difficult to develop and maintain road networks. As such, Peru and other countries with rougher topographies tend to have less dense networks; according to recent estimates, a 1 percent increase in roughness is associated with about a 1 percent decline in the number of kilometers

FIGURE 2 ■ Natural Geography



Source: Authors' calculations based on data from INEI.
The maps in the figure show the average temperature, average precipitation, median altitude of the corresponding municipal capitals, and standard deviation of these altitudes, for each of Peru's departments.

of roadway in a given area (see Ramcharan, 2009). Clearly, a region's degree of roughness affects the time and effort required to move goods through it.

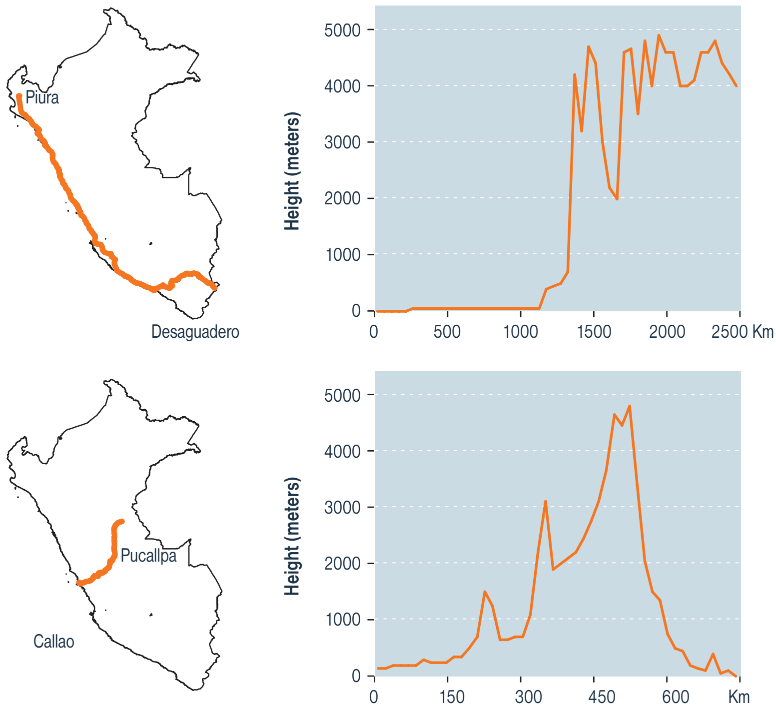
This geographical reality does not go unnoticed by the 7,500 Peruvian firms that registered exports in 2009. One of these firms, Industria Textil Piura, is a textile manufacturer located in the northern province of Piura, less than 100 kilometers from the border with Ecuador. Established in 1976, the company exports US$6 million annually in yarns to more than 10 countries, including Bolivia, Argentina, and the United States. Exports to Bolivia are shipped 2,500 km south to Desaguadero on Lake Titicaca, which Peru shares with that country, and then 105 km to La Paz, the final destination (see Figure 3, upper panel). As such, internal distance accounts for more than 95 percent of the total distance from the plant to the consumer market in the importing country.

While the domestic transportation portion of the company's shipments to Bolivia may be extreme, it is far from negligible for its exports to other destinations. Yarns exported by air to Argentina and the US must first be carried some 1,000 km south to the Jorge Chávez International Airport in Callao; the share of domestic travel distances in total distances to Buenos Aires and Miami are 25.3 percent and 20.1 percent, respectively.

Not everything is about distance, though. This is illustrated by the case of Maderas Peruanas, a firm located in Pucallpa in the eastern province of Coronel Portillo that exports some US$1.3 million wood products to several countries, including Ecuador, Mexico, and France. All of these products are shipped from the port of Callao, located at a distance of nearly 750 kilometers from their origin. This distance represents between 6 percent and 60 percent of the total distance to the destination ports in importing countries (see Figure 3, bottom panel). More importantly, several of the roads over which the goods must be transported are not paved, and the route through the Andes requires that vehicles must ascend and descend more than 4,000 meters in altitude.

Several hundred similar stories can be told merely by examining spatially referenced trade data. The message of all these stories clearly is that domestic transport infrastructure is a key determinant of transport costs incurred in reaching exit points, and that this infrastructure is likely

FIGURE 3 ■ Industria Textil Piura's Export Route to Desaguadero and Maderas Peruanas' Export Route to Callao



Source: Authors' calculations based on data from MTC and SUNAT.
The two maps in the figure show the least-cost routes between Piura and Desaguadero (top) and Pucallpa and Callao (bottom) as calculated by the method outlined in the Appendix and their respective altitude profiles.

to affect the export success of firms and the regions in which they are located. A few empirical studies have carefully examined the impact in Peru of domestic public infrastructure on economic outcomes, such as productivity, total household income and expenditures and their sources and composition, total labor hours and labor allocation across activities, and price dispersion and sales of agricultural products (e.g., potatoes).[1] However, to our knowledge, no studies have been made on the effect of this infrastructure on international trade. The aim of this chapter is to

[1] See, e.g., Escobal and Torero (2000), Escobal (2005), Escobal and Vásquez (2005), Escobal and Ponce (2011), and IPE (2003).

help fill this gap by analyzing how internal road infrastructure and hence transport costs affect Peruvian regional exports. In so doing, the analysis applies the methodological approach outlined in Chapter 1 to a rich export dataset and detailed transport surveys covering the period 2001–2009.

Regional Trade Patterns

Peru is organized into 25 departments, which are subdivided into a total of 195 provinces, and further into 1,841 districts. Geographically, the country can be seen as comprising three natural regions: the Costa (coast), the Sierra (mountains), and the Selva (the Amazon region).[2] Lima, the country´s capital, is located on the coast (see Figure 4).

These geographical regions correlate with an uneven spatial distribution of economic activity. The densely populated Costa region consists of nine departments, which comprise only 13.1 percent of the national territory but account for 55.1 percent of its total population, 70 percent of total GDP, and almost 80 percent of manufacturing GDP. The Lima region alone accounts for more than 30 percent of the population and 50 percent of GDP. This is approximately equal to the entire Sierra region's population and more than double of its total GDP. The five departments corresponding to the Selva region are sparsely populated. They comprise 50 percent of the country's total area but only account for 9.3 percent of its population, roughly 5 percent of total GDP, and less than 4 percent of manufacturing GDP (see Figure 5).[3]

We characterize regional trade patterns through the use of highly disaggregated export data for the years 2001, 2003, 2005, and 2009 collected by the Peruvian customs (SUNAT) and kindly provided by Peru's trade and tourism promotion organization PROMPERU. Each record

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[2] Some authors argue that the three-region classification is not sufficient to properly characterize Peru's actual geographic diversity (see, e.g., Pulgar Vidal, 1986, and Peñaherrera 1986).

[3] In a series of alternative maps, specific color intensities are allocated to each department depending on its rank in the variable in question. These maps essentially convey the same message, although of course in a less stylized manner. These maps are available from the authors upon request.

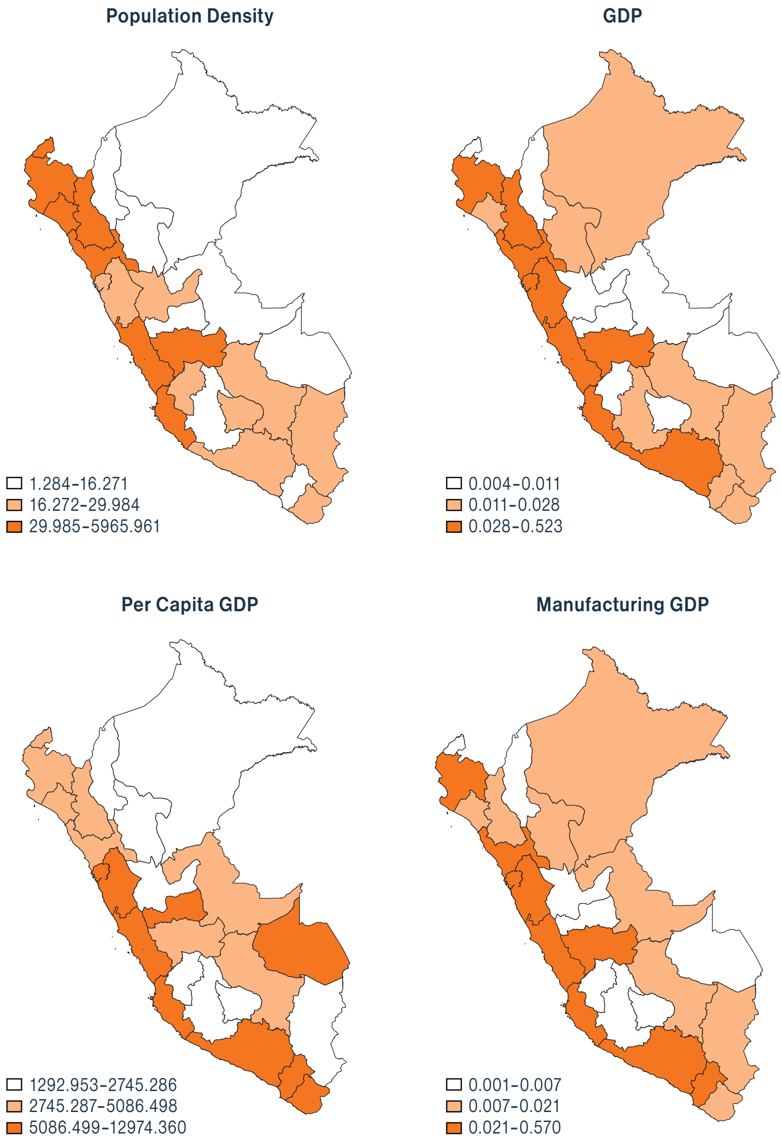
FIGURE 4 ■ Departments and Natural Regions

Source: Authors' elaboration based on data from INEI (1995).
The figure shows the distribution of the departments across the three natural regions:
Region 1 – Selva (white): Amazonas, Loreto, Madre de Dios, San Martín, and Ucayali.
Region 2 – Sierra (light orange): Ancash, Apurimac, Arequipa, Ayacucho, Cajamarca, Cusco, Huancavelica, Huánuco, Junín, Pasco, and Puno.
Region 3 – Costa (dark orange): Callao, Ica, La Libertad, Lambayeque, Lima, Moquegua, Piura, Tacna, and Tumbes.

identifies the municipality of origin, the product (10-digit Harmonized System), the customs through which the goods leave the country, the value in US dollars, and the quantity (weight) in kilograms.

These data reveal that Peruvian total exports amounted to US$27 billion in 2009; in nominal terms this was almost 300 percent greater than at the beginning of the decade and represented 21.1 percent of the GDP, up from 12.7 percent in 2001 and from 8.9 percent in 1991. This expansion can be traced back to an increase in quantities shipped

FIGURE 5 ■ Economic Geography



Source: Authors' calculations based on data from INEI.
The maps show each department's ratio of population to area, share in the country's GDP, ratio of GDP to population, and share in the country's manufacturing. GDP per capita is expressed in US dollars. Data correspond to 2009.

abroad—57 percent in terms of weight—and particularly to the price rises of the country's main export products. These products are essentially primary goods or resource-based manufactures according to the classification suggested by Lall (2000), primarily gold, copper, zinc, lead, and tin.[4] As a group, primary products account for more than three quarters of Peru's total export values and weight (see also Giordano et al., 2006).

Unsurprisingly, trade outcomes also show clear heterogeneous regional patterns. The departments in the Costa region have accounted for nearly two thirds of the country's total exports in the last decade. In the most recent years, however, the export share of these departments declined, both in terms of value and quantity (weight) (see Table 1). The reduction has been particularly pronounced in Lima. In contrast, the exports in the Sierra region increased their aggregate shares by 7.6 and 4.9, respectively. In this group, Ancash, Pasco, and especially Arequipa stand out. Other Sierra departments such as Cusco, Huancavelica, and Huánuco, and all Selva departments saw either little change in their shares or even experienced reductions. As suggested below, lack of adequate infrastructure may help explain why these departments have not been able to benefit more from increased openness to international trade in recent decades.

Relative specialization patterns also certainly played a role in explaining relative export performance differences among the three regions. The coastal departments represent almost three quarters of total Peruvian manufacturing foreign sales and their share increases to an impressive 97 percent and 99 percent, respectively, for medium- and high-technology manufactures. Still, goods in these latter groups together represent less than 5 percent of the country's aggregate exports. In short, these products are relatively unimportant in Peru's export basket and their low levels of exports are extremely spatially agglomerated.

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[4] Lall's classification differentiates among primary products, resource-based manufactures, low-technology manufactures, medium-technology manufactures, and high-technology manufactures.

Table 1 ■ Department Shares in Export Values and Weight

	Export Value		Export Weight	
Region/Department	**2001**	**2009**	**2001**	**2009**
Costa	69.7	62.8	78.0	75.3
Sierra	28.8	36.4	19.2	24.1
Selva	1.5	0.8	1.7	0.6
Lima	35.2	25.5	20.0	10.0
Ancash	9.3	10.8	9.4	11.2
Ica	6.4	9.0	33.4	38.0
Arequipa	3.8	8.8	1.5	6.0
Cajamarca	3.5	8.5	0.0	0.5
La Libertad	3.1	7.6	1.5	2.4
Callao	8.3	7.3	10.9	10.3
Moquegua	8.1	7.0	3.2	4.4
Piura	5.2	4.5	8.1	9.1
Pasco	1.4	2.8	2.7	3.5
Junín	6.8	2.3	3.2	1.8
Puno	0.6	1.3	0.1	0.0
Lambayeque	1.2	0.8	0.4	0.5
Cusco	2.0	0.7	1.9	0.3
Tacna	1.2	0.6	0.4	0.2
Huancavelica	0.9	0.5	0.0	0.3
Tumbes	0.3	0.4	0.1	0.3
Apurimac	0.0	0.4	0.0	0.1
San Martín	0.3	0.3	0.1	0.1
Ayacucho	0.0	0.2	0.0	0.2
Loreto	0.6	0.2	0.4	0.2
Ucayali	0.2	0.2	0.1	0.2
Madre de Dios	0.1	0.1	0.0	0.1
Huánuco	0.2	0.1	0.4	0.1
Amazonas	0.3	0.0	1.1	0.0

Source: Authors' calculations based on data from SUNAT.

The relative importance of the Costa region as an origin for exports drops to 56 percent for primary products. The remaining 44 percent of these products comes almost entirely from the Sierra region, which is highly specialized in this kind of products. Indeed, more than 90 percent of exports from the Sierra have consisted of primary and resource-based goods in recent years. The departments in the Selva region are similarly specialized. For example, while Amazonas and San Martín are mainly export primary products, Loreto and Ucayali concentrate on resource-based manufactures. Consistently, nine Sierra and Selva departments appear in the first half of a departmental ranking according to the share of heavy products in the respective total exports (see Figure 6).

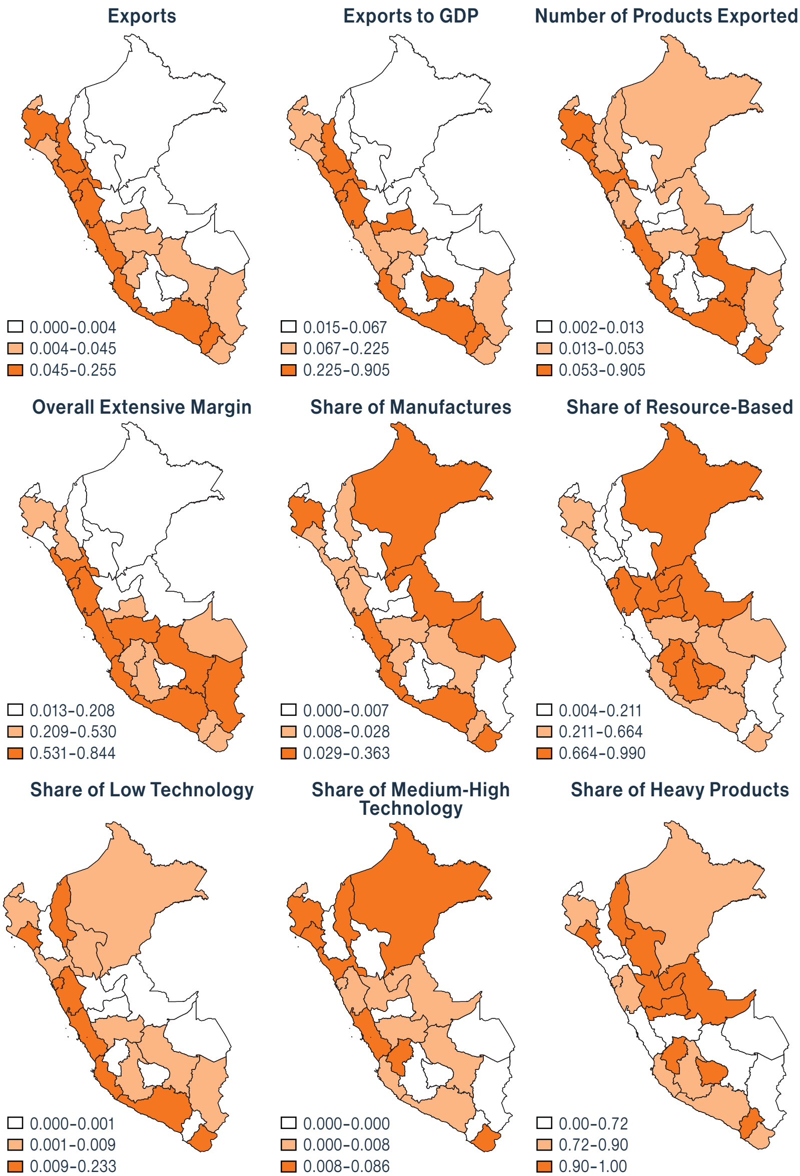
The multidimensional differences in export outcomes across regions can be summarized into a single-valued measure by means of a generalized distance measure (see Barnett, 1976). The resulting univariate indicator can be used to rank and classify these regions into groups that have a similar overall export development levels. Factoring in the country's three well-defined geographical regions and using a version of this summary measure combining information on the level and diversification of exports (ratio of exports to GDP and number of products exported), we identify three groups of departments to assess to what extent natural and export-driven groupings overlap. These export groups are as follows:

- High export performers: Ancash, Arequipa, Cajamarca, Callao, Ica, Lima, Moquegua, and Pasco.
- Intermediate export performers*:* Apurimac, Junín, La Libertad, Lambayeque, Piura, Puno, Tacna, and Tumbes.
- Low export performers*:* Amazonas, Ayacucho, Cusco, Huancavelica, Huánuco, Loreto, Madre de Dios, San Martín, and Ucayali (see Figure 7).[5]

These groups are virtually identical when the aggregate indicator also considers the share of manufacturing products in total exports as a grouping variable. The only difference is that Huancavelica and Puno switch groups.

[5] In reducing each multivariate observation to a single value, differences are computed relative to the respective maximum and covariances across observations are taken into account. Specifically, this single value is equal to the vector of the differences between the values of each department's export outcomes and the maximum values of the respective outcome multiplied by the variance-covariance matrix and its transpose.

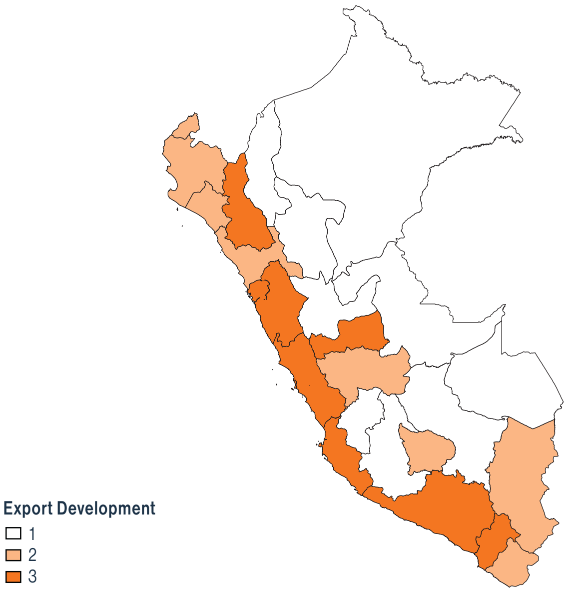
FIGURE 6 ■ Regional Trade Patterns



Source: Authors' calculations based on data from SUNAT.

The maps show each department's share in the country's total exports, ratio of exports to GDP, ratio of the total number of products it exported to the total number of products exported by the country, extensive margin (diversification) indicator proposed by Hummels and Klenow (2005), and share of manufactures, resource-based manufactures, low-technology manufactures, medium- and high-technology manufactures, and heavy products (products with weight to value ratios above the median as determined using worldwide trade data over the period 1996-2010) in the regions' total exports. Data correspond to 2009.

FIGURE 7 ■ Group of Regions According to Export Development Levels



Source: Authors' calculations based on data from SUNAT.

The map shows the three groups of departments according to export development levels as determined from their export-to-GDP ratio and total number of products exported. High export performers (orange) are Ancash, Arequipa, Cajamarca, Callao, Ica, Lima, Moquegua, and Pasco; intermediate export performers (light orange) are Apurimac, Junín, La Libertad, Lambayeque, Piura, Puno, Tacna, and Tumbes; and low export performers (white) are Amazonas, Ayacucho, Cusco, Huancavelica, Huánuco, Loreto, Madre de Dios, San Martín, and Ucayali. Data correspond to 2009.

The median export-to-GDP ratios of these groups are 0.529, 0.183, and 0.040, respectively; their median ratios of products exported relative to Peru's total are 0.060, 0.046, and 0.013, respectively. Their median shares of manufacturing are 0.026, 0.016, and 0.010, respectively. These summary measures convey a straightforward message: departments in the Sierra region, and even more in the Selva region, lag in export performance. In this group of less export-developed regions, the former indicators range from 0.015 (Amazonas) to 0.122 (Huancavelica), and from 0.005 (Madre de Dios and Huancavelica) to 0.053 (Cusco).

The average (median) total number of products exported by the departments classified within this group is almost 80 (60), with Huancavelica, Huánuco, and Madre de Dios at the bottom of the distribution with 23, 29, and 24 products, respectively, and Cusco at the top with 233 products. Table 2 lists the three most important products in the departments' export baskets along with respective percentage shares in their total foreign sales. Figures reported clearly indicate that agriculture-related products account for relatively large shares of ag-

Table 2 ■ Three Most Important Export Products in the Less Export-Developed Departments

Department	Ranking	Product	Share
Amazonas	1	Coffee, not roasted, not decaffeinated	0.914
	2	Flours, meals and pellets of fish	0.045
	3	Syringes, needles, catheters, and cannulae, and the like	0.011
		Total	0.970
Ayacucho	1	Zinc ores and concentrates	0.375
	2	Lead ores and concentrates	0.263
	3	Gold, unwrought	0.127
		Total	0.765
Cusco	1	Gold, unwrought	0.387
	2	Refined copper, cathodes, and sections of cathodes	0.280
	3	Copper ores and concentrates	0.247
		Total	0.914
Loreto	1	Wood of tropical species sawn or chipped lengthwise, sliced or peeled	0.278
	2	Petroleum oils and oils obtained from bituminous minerals, other than crude	0.171
	3	Non-coniferous woods continuously shaped	0.154
		Total	0.604
Huancavelica	1	Copper ores and concentrates	0.542
	2	Lead ores and concentrates	0.382
	3	Zinc ores and concentrates	0.066
		Total	0.990
Huánuco	1	Lead ores and concentrates	0.503
	2	Cocoa beans, whole or broken, raw or roasted	0.162
	3	Zinc ores and concentrates	0.157
		Total	0.822

Continued on next page

Table 2 ■ Three Most Important Export Products in the Less Export-Developed Departments *(continued)*

Department	Ranking	Product	Share
Madre de Dios	1	Gold, unwrought	0.652
	2	Non-coniferous woods continuously shaped	0.166
	3	Brazil nuts, shelled	0.135
		Total	0.953
San Martín	1	Coffee, not roasted, not decaffeinated	0.882
	2	Cocoa beans, whole or broken, raw or roasted	0.040
	3	Molybdenum ores and concentrates, others	0.020
		Total	0.942
Ucayali	1	Non-coniferous woods continuously shaped	0.556
	2	Wood sawn or chipped lengthwise, sliced or peeled, others	0.199
	3	Plywood consisting solely of sheets of wood, others	0.050
		Total	0.804

Source: Authors' calculations based on data from SUNAT.
The table presents the three main export products along with their respective and cumulative shares for each department in the less export-developed group. Data correspond to 2009.

gregate exports for departments in the Selva region, whereas their counterparts in the Sierra region are extremely specialized in metals exports. Thus, wood products account for more than 40 percent of Loreto's exports and more than 80 percent of Ucayali's exports. In turn, copper represents more than 50 percent of total exports in Cusco and Huancavelica; the same holds for Ancash and Arequipa. Similarly, gold accounts for more than 60 percent of total foreign sales in Cajamarca and Puno.

Peru's Road Network and Regional Transport Costs

Road transportation is Peru's main transport mode, and roads carry approximately 95 percent of the country's cargo (see MTC, 2007a). The road system primarily consists of national and departmental routes. The former interconnect the country longitudinally and transversely to create transport and commercial links with neighboring nations, connect departmental capitals with each other and with the main production and consumption centers, and provide access to national and international ports, airports, and railways.

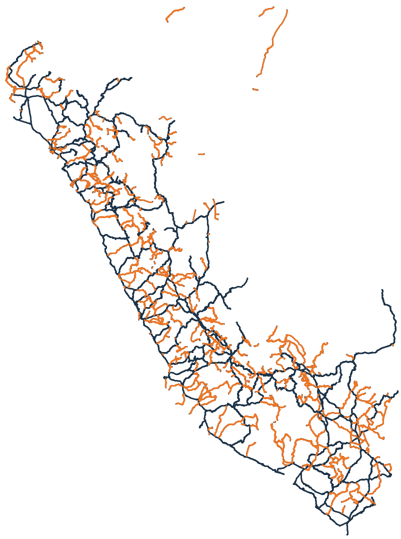
The national routes total 23,596 km, of which nearly 50 percent are paved and more than 60 percent traverse areas with moderate to steep slopes (gradients larger than three). The departmental routes have a total length of approximately 23,000 km and connect the departmental capitals with the provincial capitals, each of these capitals with each other, and with municipalities in different provinces; these connections facilitate the movement of people and goods at the regional level and provide links to regional ports and airports (see MTC, 2005, 2010, 2011a, and Zecerrano Mateus, 2011).[6] These networks are shown in Figure 8.

As these figures show, the country's road coverage varies greatly from region to region. The network is relatively dense in the Costa region, notably less so in the Sierra region, and very thin in the Selva region. Thus, while the road density in Lima is 0.093 km per squared km, it is at least ten times lower in Loreto, Madre de Dios, and Ucayali, where it ranges between 0.002 and 0.007. In consonance with what has been discussed in the introduction to this chapter, road infrastructure at least partially appears to be conditioned by the country's physical geography.

Export goods must first be shipped from their place of origin to customs along these roads. Peru has 20 customs, which are distributed across the country, as shown in Figure 9. The distribution of departmental exports across these customs is presented in Figure 10. Callao clearly has the most important customs in the country, handling more than 60 percent of Peru's total exports and serving as the main customs for more than half of the departments (14 out of 25), with an average share of more than 90 percent for these departments. Remaining exports are handled by customs in Chimbote, Ilo, Mollendo-Matarani, and Paita, whose shares are 8.2 percent, 7.3 percent, 6.2 percent, and 5.3 percent, respectively. In addition, exports from some departments leave the country primarily through customs located within their borders or in a nearby department. This is the case with Ancash (Chimbote), Moquegua (Ilo), Arequipa

[6] Remaining routes form the local road network. These routes are mostly unpaved (almost 99 percent) and are generally in bad shape (see MTC, 2005). As a consequence, they are infrequently used for international trade shipments.

FIGURE 8 ■ National and Departmental Road Networks

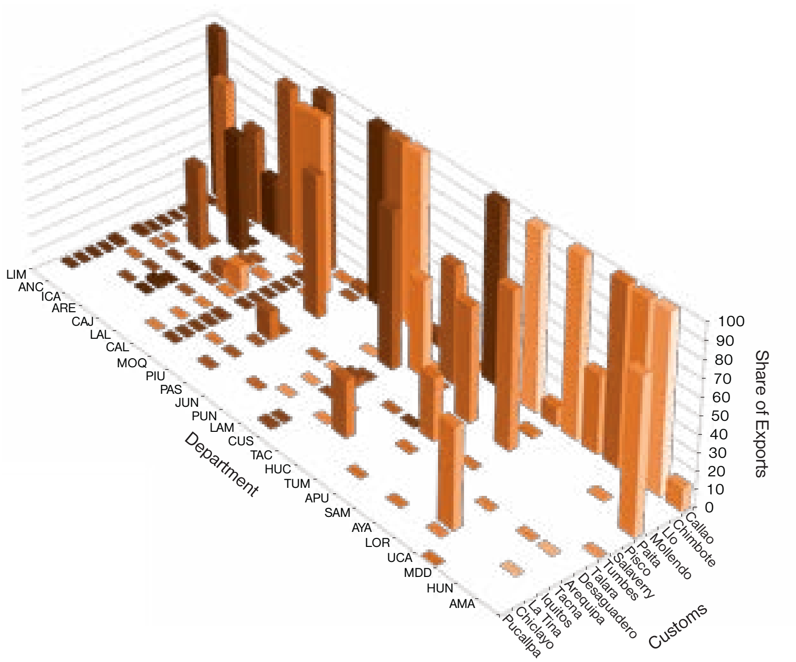


Source: Authors' calculations based on data from MTC.
The map shows the national (blue) and departmental (orange) road networks.

FIGURE 9 ■ Location of Customs

Source: Authors' elaboration based on data from SUNAT.
The map shows locations of the country's customs.

FIGURE 10 ■ Distribution of Departmental Exports by Customs



Source: Authors' calculations based on data from SUNAT.
The figure shows the share of each department's exports that is handled by each customs. Data correspond to 2009.

(Mollendo-Matarani), Piura (Paita), Tacna (Ilo), Cusco (Mollendo-Matarani), and Lambayeque (Paita). In Loreto, only a few municipalities are connected to the road network that provides links with the rest of the country; at best, cities only have road access to Iquitos, the department's capital, through whose customs they predominantly export.

Using georeferenced information from the MTC on the municipalities, the customs offices, the connecting national and departmental routes, the quality of the different segments of these routes (paved vs. non-paved roads) and the type of the terrain they cross (varying degree of gradients), and taking into account the corresponding distance- and time-related cost factors from surveys conducted by the ministry, we can compute the optimal (least cost) route for each combination of municipalities and customs and the associated transport costs. These calculations are presented in the Appendix.

Table 3 reports percentiles of the distribution of the distances to the main customs corresponding to the optimal routes across exporting municipalities and exported products along with the average and the average share of paved segments for each Peruvian department in 2009.

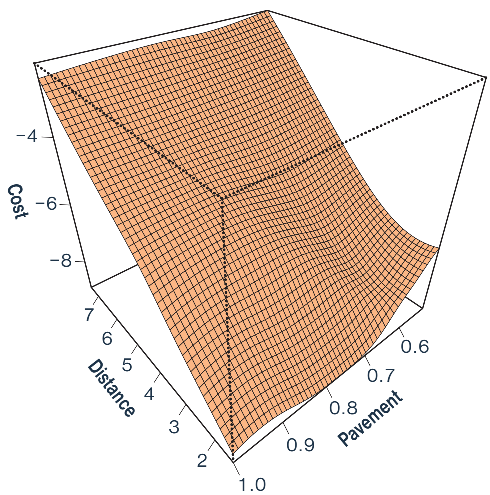
Table 3 ■ Distance to Main Customs and Share of Paved Roads

	Distance to Main Customs				Share Paved
Department	**p10**	**p50**	**p90**	**Mean**	**Mean**
Madre de Dios	1,352.4	1,669.1	1,794.8	1,568.1	0.825
Amazonas	1,207.2	1,207.2	1,207.2	1,186.3	0.564
Cusco	1,131.3	1,139.1	1,146.7	1,104.5	0.974
Puno	417.2	1,302.5	1,341.7	1,010.0	0.807
Cajamarca	744.2	865.8	1,891.6	961.5	0.764
Apurimac	819.0	819.0	1,147.7	922.4	0.679
Arequipa	142.7	1,048.5	1,175.0	903.9	0.944
San Martín	661.8	977.3	980.3	875.9	0.629
Ucayali	748.1	750.8	750.8	740.8	0.544
Huancavelica	433.6	440.6	1,683.1	640.7	0.664
La Libertad	504.8	579.0	697.1	593.0	0.954
Ayacucho	578.1	586.3	587.5	589.6	0.746
Huánuco	380.0	499.8	898.8	550.1	0.536
Lambayeque	259.1	474.0	807.8	526.5	0.963
Ancash	346.1	445.2	527.0	428.6	0.986
Junín	205.6	326.0	457.5	374.9	0.968
Piura	0.0	126.9	1,135.9	354.0	0.879
Tumbes	0.0	29.8	1,276.1	348.2	0.668
Ica	225.7	260.6	484.5	315.7	0.954
Pasco	230.6	285.6	396.1	299.8	0.512
Moquegua	0.0	4.0	1,223.2	209.1	0.964
Lima	21.8	35.9	174.2	156.0	0.995
Callao	0.0	0.0	14.8	110.6	0.988
Loreto	0.0	0.0	29.3	32.4	0.513
Tacna	0.0	0.0	0.0	22.1	0.944

Source: Authors' calculations based on data from MTC and SUNAT.
The table presents the (simple) average and the 10th, 50th (median), and 90th percentiles of the distribution of the distances to the respective main customs for each department (as determined by their shares in total municipal product exports) along with the average share of paved segments in the respective roads used. Data correspond to 2009.

These figures indicate that goods from the departments in the Sierra and Selva regions require shipping over substantially longer distances to reach customs. The average (median) distance exceeds 1,000 km (1,100 km) for Amazonas, Cusco, Madre de Dios, and Puno, but it is less than 200 km (40 km) for the coastal departments of Callao, Lima, and Tacna. For the reasons explained above, the same also holds for Loreto, which is located in the Selva region. The relatively short distances appearing in the table primarily correspond to municipalities close to Iquitos that are linked by road to that city, through whose customs a substantial portion of the region's exports are shipped abroad. In addition, shipments from several departments in the Sierra and Selva regions such as Amazonas, Huancavelica, Huánuco, Loreto, San Martín, and Ucayali, must take routes with a relatively low percentage of paved segments, which makes transportation more difficult. In general, distance and quality of roads determine transport costs. This can be clearly seen in Figure 11. In particular, departments far from the main customs offices, or whose

FIGURE 11 ■ Distance, Road Quality, and Per Unit Transport Costs



Source: Authors' calculations based on data from MTC and SUNAT.
The 3D plot illustrates the relationship between the (natural logarithm of the) per unit transport costs to the main customs, the (natural logarithm of the simple) distances to the main customs, and the share of paved segments in the roads used to reach these customs. Data correspond to 2009.

routes to these locations are hard to transit, can be expected to face high transport costs.

Topography and particularly roughness also help determine spatial variations of transport costs. Table 4 presents the percentiles of the

Table 4 ■ Adjustments to Real Distance to Main Customs Ratio

Department	p10	p50	p90	Mean
Pasco	1.453	1.643	2.084	1.703
Apurimac	1.219	1.873	1.873	1.682
Ucayali	1.582	1.582	1.585	1.586
Loreto	1.004	1.538	2.035	1.582
Huánuco	1.433	1.576	1.904	1.576
San Martín	1.166	1.606	1.790	1.566
Madre de Dios	1.484	1.553	1.582	1.553
Huancavelica	1.159	1.473	2.035	1.548
Junín	1.315	1.347	1.681	1.390
Puno	1.126	1.143	1.805	1.388
Ayacucho	1.273	1.278	1.588	1.381
Tacna	1.101	1.210	2.002	1.298
Cusco	1.250	1.250	1.396	1.293
Arequipa	1.068	1.193	1.688	1.266
Amazonas	1.205	1.205	1.205	1.213
Ica	1.092	1.106	1.576	1.205
Moquegua	1.007	1.115	1.490	1.172
Cajamarca	1.110	1.110	1.243	1.142
Ancash	1.014	1.162	1.315	1.135
Lima	1.022	1.097	1.157	1.089
Piura	1.016	1.037	1.350	1.087
Callao	1.002	1.054	1.180	1.077
Tumbes	1.001	1.080	1.085	1.056
La Libertad	1.019	1.019	1.094	1.055
Lambayeque	1.009	1.038	1.063	1.034

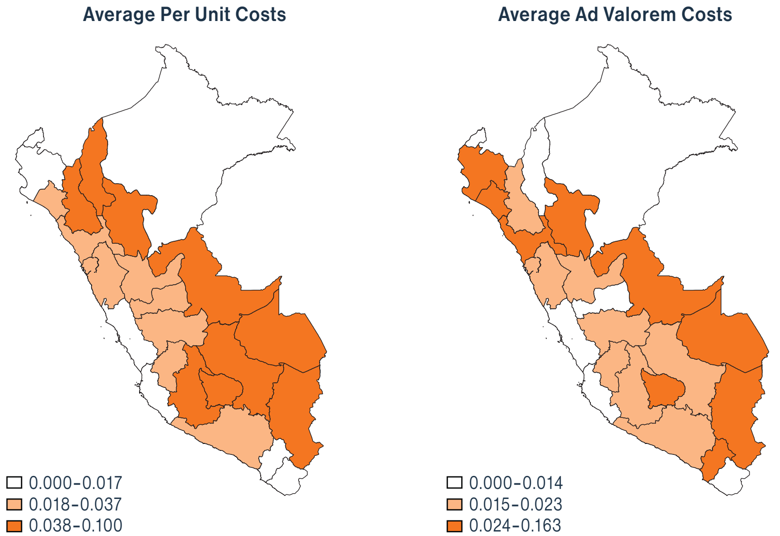
Source: Authors' calculations based on data from MTC and SUNAT.

The table presents the (simple) average and the percentiles 10th, 50th (median), and 90th of the distribution of the ratio of the distances to the respective main customs (as determined by their shares in total municipal product exports) for each department adjusted by the type of surface of the roads (paved vs. non-paved) and the geographic characteristics of the areas these roads go through (gradients) to the respective real, unadjusted distances. Data correspond to 2009.

distribution of ratios of distances adjusted to take into consideration the quality of the routes and the gradients in different segments (as detailed in the Appendix) to original distances for each Peruvian department in 2009. These ratios reveal that, when factoring in additional obstacles presented by geography and poor infrastructure, actual distances to the main customs of departments such as Pasco, Apurimac, Ucayali, Loreto, Huánuco, San Martín, Madre de Dios, and Huancavelica are at least 50 percent greater than they would be if all their roads were paved and ran along flat surfaces. It is important to note that six out of nine of the less export-developed departments belong to the group with the ten largest distance adjustments, and hence the less favorable infrastructure and orographic conditions.

Figure 12 shows transport costs resulting from types of road surfaces and characteristics of terrains along with the distance- and time-related factor costs for each department. As can be seen, Ayacucho, Huancavelica, Huánuco, Madre de Dios, and Ucayali have relatively high transport costs

FIGURE 12 ■ Transport Costs, Per Unit and Ad Valorem



Source: Authors' calculations based on data from MTC and SUNAT.
The maps show the per unit and ad valorem transport costs to the main customs office of each department as calculated with the method outlined in the Appendix. Data correspond to 2009.

per ton. A similar picture generally emerges when considering instead ad valorem transport costs. As expected, however, figures are not entirely symmetric. The reason is that computation of the latter costs also takes into account values and quantities actually traded along the route.

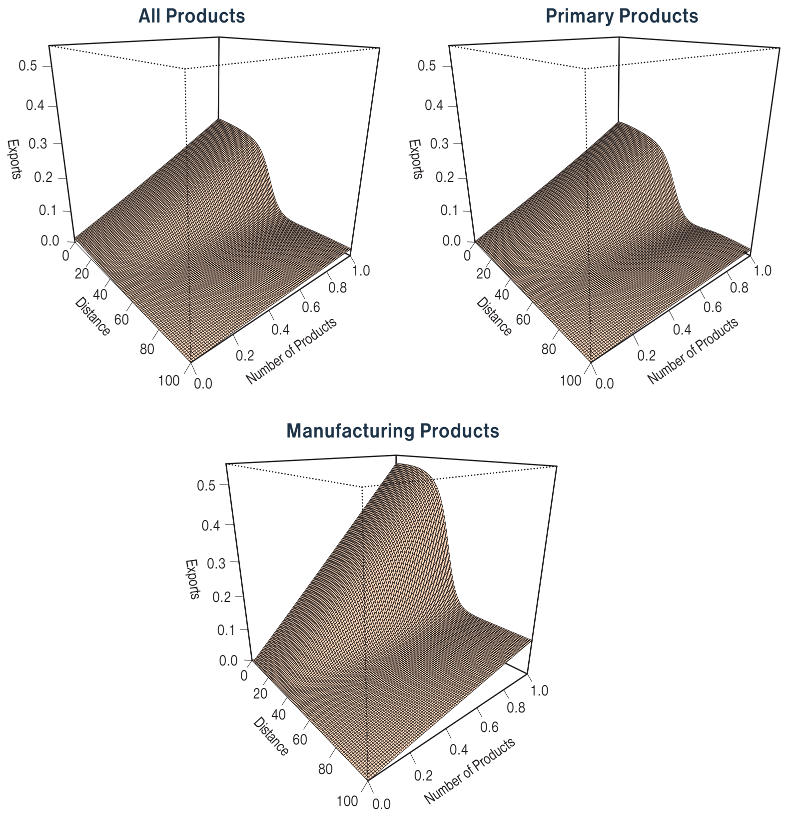
Domestic Transport Costs and Regional Exports: Preliminary Evidence

We have seen both significant regional disparities in export performance and pronounced regional patterns in internal transport costs. The question then arises: To what extent are a region's export performance and its transport costs related? Figure 13 provides a preliminary answer to this question.[7] This figure shows the distribution of export shares and that of ratios of products exported relative to the national total over distance to customs, both overall and for different goods categories. The origins that are closest to customs account for a substantial portion of the total exports and have significantly more diversified foreign sales; i.e., these origins export more along both the extensive margin (number of products) and the intensive margin (average exports per product). More specifically, municipalities within 50 km from customs represent more than 40 percent of total exports and approximately 90 percent of goods shipped abroad by the country as a whole. As expected, these disparities are more pronounced for manufacturing goods than for primary goods; the production of primary goods is more spatially related to places where the natural resources are available, which tend to be distributed throughout the territory.[8] In the case of manufacturing exports, the share of municipalities within 50 km from customs reaches 84 percent, whereas in the case of primary goods' exports, only 38 percent.

[7] The 3D plots show the predicted values of exports from a non-parametric regression. These values are the conditional means estimated on each combination of values of distance and number of products exported using a local-linear estimator, where for each point the conditional means are approximated by a linear function that takes into account the distance of each observation to the point weighted by a kernel function.

[8] It might also be argued that more urbanized areas have larger and more diversified manufacturing exports, whereas in rural areas extractive activities prevail.

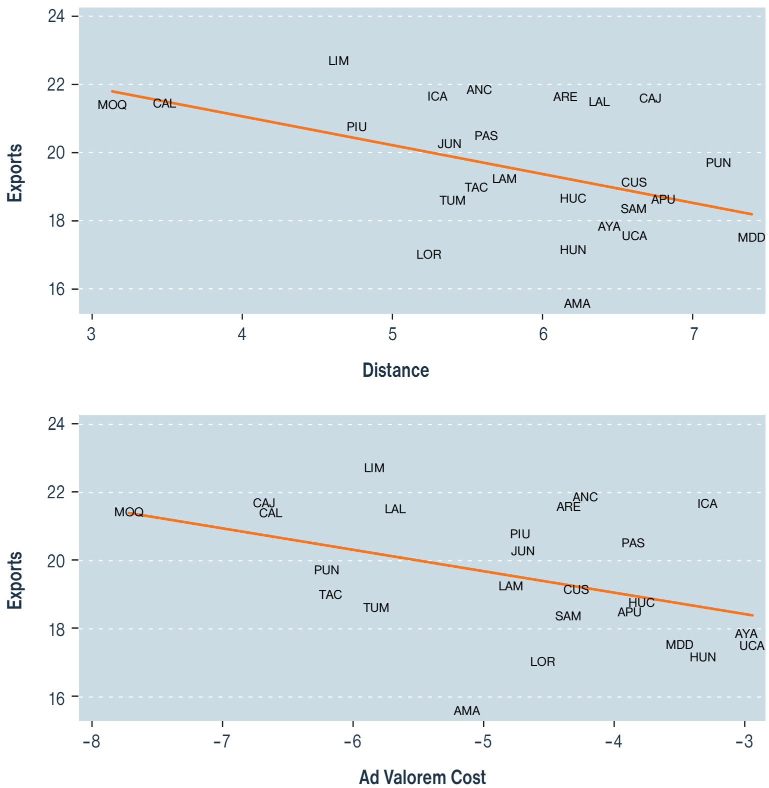
FIGURE 13 ■ Export Values, Number of Products, and Distance to Customs



Source: Authors' calculations based on data from MTC and SUNAT.
The figures show the share of exports and the ratio of the number of products exported to the total number of products exported by the country over distances to customs. Distances have been discretized in 25-km intervals. Products are classified as primary or manufacturing according to the WTO classification. Data correspond to 2009.

The scatter plots in Figure 14 present further evidence in this regard. The figure on the top shows a negative association between total departmental exports and distance to customs, whereas the figure on the bottom confirms that this is also the case with these exports and ad valorem transport costs. Although similar, the relative positions of the regions, and accordingly the relationships, are not identical. As it should be clear from the discussion above, this difference is at least partially explained by differences in the quality of the routes.

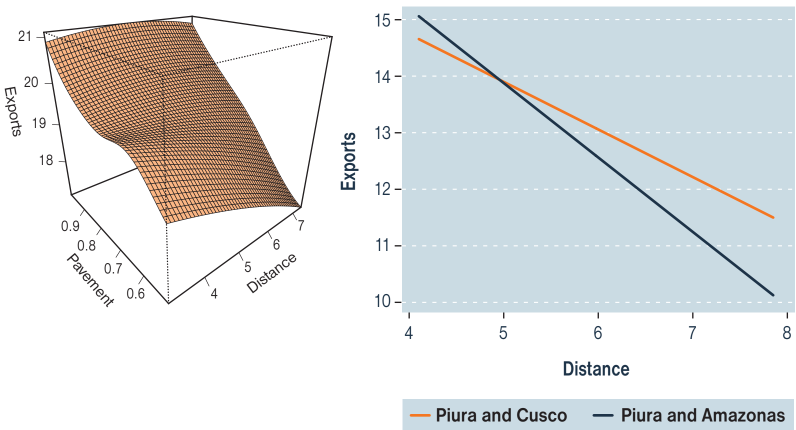
FIGURE 14 ■ Transport Costs and Departmental Exports



Source: Authors' calculations based on data from MTC and SUNAT.
The scatter plots in the figure show the relationship between the (natural logarithm of the) total departmental exports and the (natural logarithm of the weighted average of the) distances to customs (top) and between the (natural logarithm of the) total departmental exports and the (natural logarithm of the weighted average of the) ad valorem transport costs to customs (bottom). Dots identify departments. The downward sloping curves are the linear fits. Data correspond to 2009.

Figure 15 highlights this interplay between exports, distance, and the type of roads. The plot on the left generally suggests that regional exports are negatively associated with both average distance to the main customs and average share of non-paved roads. The plot on the right, illustrates the incidence of the treatment of the road surface with two concrete examples: the relationship between exports and distance for two pairs of departments—Piura and Amazonas, and Piura and Cusco—whose routes to their main customs have different proportions of paved segments

FIGURE 15 ■ Exports, Distance, and Quality of Roads



Source: Authors' calculations based on data from MTC and SUNAT.
The 3D plot on the left shows the relationship between the (natural logarithm of) total departmental exports, the (natural logarithm of the) distances to the main customs, and the proportion of paved segments in the route used to reach these customs. The figure on the right presents the linearly fitted relationship between the (natural logarithm of) total municipality exports by customs and the (natural logarithm of the) distance for each pair of departments. Data correspond to 2009.

(see Table 2). The curves indicate that, at similar long distances, Cusco, with more paved roads, has consistently more exports.

The Impact of Domestic Transport Costs on Regional Exports: Empirical Assessment

While the relationships identified above certainly suggest that domestic transport can act as a barrier to trade, a more rigorous examination of this relationship is needed to draw more definitive conclusions. We therefore turn to a more formal analysis of this relationship to address the question: what are the effects of internal transport costs on exports? Our analysis answers this question by looking at both the level and the composition of the foreign sales.

Disaggregated Export Levels: We first estimate an equation that relates municipal exports at the product level through potentially different customs with the corresponding ad valorem transport costs while controlling for permanent municipality-product-customs characteristics and year-specific factors.[9] We arrive at the following:

Table 5 ■ Municipal Exports by Product and Transport Costs: Baseline Estimating Equation

Determinants of Municipal Exports at the Product Level
Ad Valorem Transport Costs between Municipality and Customs (–)
Permanent Municipality-Product-Customs Specific Characteristics
Year-Specific Factors

Note: The expected sign of the estimated coefficient on the variable of interest appears between parentheses.

This equation is first estimated pooling across all products (10-digit Harmonized System) to arrive at an approximate average measure of the effect of domestic transport costs on exports. In this case, we also alternatively control for municipality, product, or customs characteristics varying over time, and obtain similar results.[10]

Since goods vary in their transportability, the effects of transport cost on exports are likely to differ across sectors (see Hummels, 2001). For the same reason, the average impact of transport costs on trade can also be expected to be heterogeneous across regions or groups of regions with different specialization profiles. We therefore first estimate the equation distinguishing between primary and manufacturing goods, and secondarily between groups of departments based on their export development levels. Tables B2-B4 in the Appendix B.2 report the estimation results when pooling across all goods and when allowing for asymmetric responses for different product categories and subsets of regions along the lines defined above. Figure 16 (top) presents a visual representation of the estimated effects.

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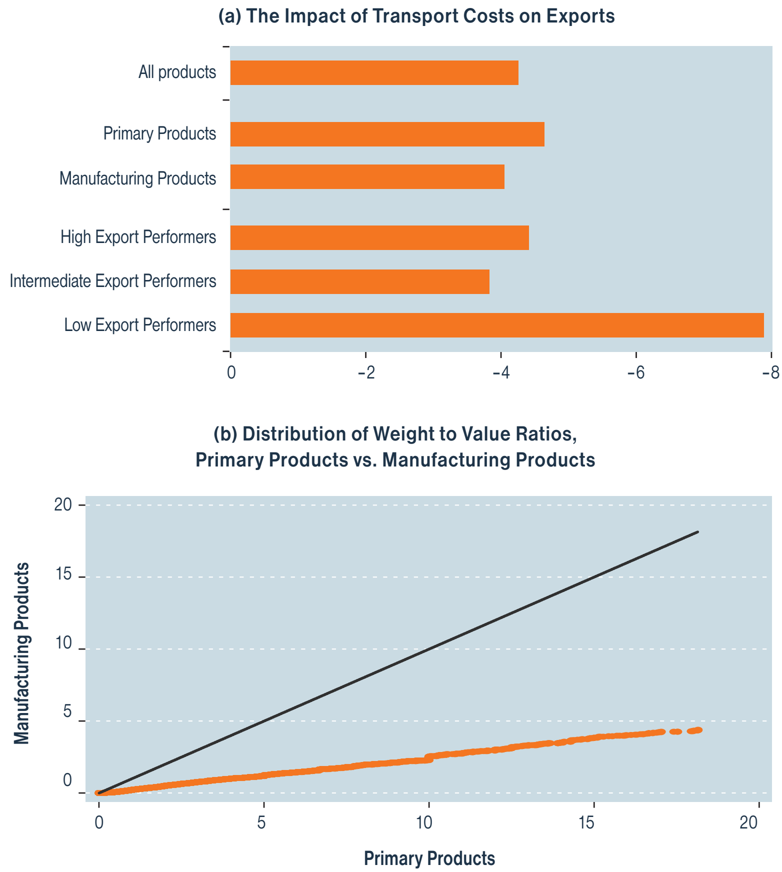
[9] We estimate a two-way fixed effects model in which we include a set of fixed effects for the panel unit (municipality-product-customs), and a set of fixed effects for the years (2001, 2003, 2005, and 2009), with one of the them serving as the omitted category.

[10] In other words, in addition, we include municipality-year, product-year, and customs-year fixed effects to reduce potential biases associated with omission of relevant variables.

FIGURE 16 ■ Transport Costs and Exports



Source: Authors' calculations based on data from MTC and SUNAT.
The figure on the top presents the effects of domestic ad valorem transport costs on exports as estimated at the product level (10-digit Harmonized System), pooling alternatively across all products, across product categories, and across groups of regions based on a specification in which the dependent and main explanatory variables are expressed in natural logarithms, and which includes municipality-customs-product fixed effects and year fixed effects. The classification proposed by the WTO is used to distinguish between primary and manufacturing products. Regions are grouped according to the above classification (see Figure 7). The sample period is 2001, 2003, 2005, and 2009. The figure on the bottom plots the distribution of the weight to value ratios of the primary goods against that of the manufacturing goods exported by Peru. Data correspond to 2009.

The average impact of domestic ad valorem transport costs on exports, as estimated in fully pooled regressions, suggests that a 1 percent reduction in these costs would lead to approximately a 4.3 percent expansion of exports.[11] The effect is larger for primary goods than for manufacturing goods, with the ratio of the respective estimated effects being 1.2.[12] This is hardly surprising given that, as shown by Figure 16 (bottom), the former are substantially heavier than the latter.[13] Furthermore, the estimated impacts are larger—almost twice as large—for less export-developed regions than for their most export-developed counterparts.[14] As referred to above, these asymmetric impacts are—at least partially—related to the export specialization of these groups of regions (see Figure 6). Admittedly, these impact estimates may be biased because of potential reverse causality. However, findings remain robust when this is properly accounted for (see Box 1).

Product Diversification: Previous estimation results indicate that domestic transport costs are far from having symmetric effects across type of products. We can therefore assume that these costs also affect the composition of the exports of Peru's various regions and are likely to shape their diversification patterns. To examine this issue more precisely, we estimate the following relationship:

Table 6 ■ Municipal Export Diversification and Transport Costs: Baseline Estimating Equation

Determinants of Municipal Export Diversification
Average Ad Valorem Transport Costs between Municipality and Customs (–)
Permanent Municipality-Customs Specific Characteristics
Year-Specific Factors

Note: The expected sign of the estimated coefficient on the variable of interest appears between parentheses.

[11] Given the theoretical model from which we implicitly derive our estimating equation, the estimated coefficient on the transport cost variable corresponds to the CES elasticity (see, e.g., Hummels, 2001, and Anderson and van Wincoop, 2004).

[12] Equations are estimated at the 10-digit Harmonized System level. Results are identical when products are defined at the 6-digit HS level. Detailed tables reporting estimates based on data at this alternative level of aggregation are available from the authors upon request.

[13] According to the test proposed by Delgado et al. (2002), the distribution of the weight to value ratios of primary products stochastically dominates that of the manufacturing products. The test statistics are available from the authors upon request.

[14] The effects are virtually identical when the group of less-export developed regions also includes Puno, and when Puno is included and Huancavelica is excluded from this group. Detailed tables with alternative estimation results are available from the authors upon request.

■ Box 1: Roads, Exports, and Beyond

Incan Roads Offer Clue to Identify the Economic Role of Present-day Transportation Network

Export development plans in developed and developing countries alike generally assume that improved infrastructure tends to generate employment by helping increase exports. Whether and to what extent this is actually the case is difficult to establish because reverse causality can affect both the relationship between internal infrastructure and exporting, and between exporting and employment.

Thus, road improvements might be seen as favoring better export performance for regions receiving infrastructure investment. But it is equally possible that increasing exports results in investments in these regions to reduce transport costs. Similarly, firms may hire more workers in response to additional demand from abroad, or they may increase their number of employees to achieve a scale that will later facilitate their ability to deepen their penetration into foreign markets. A possible strategy to break down this reverse causality is to use historical data. This is done in a study by Volpe Martincus et al. (2013a) in which the authors estimate the impact of the new roads constructed in Peru between 2003 and 2010 on firms' exports and thereby on firms' employment by positing the original Inca road network as an exogenous source of variation in transport infrastructure improvements.

Continued on next page

Box 1: (*continued*)

The Incan network (indicated in orange) was clearly built for reasons entirely unrelated to present day foreign trade, but—as suggested by the figure above—it is a good predictor of current road infrastructure changes. With the inclusion of an appropriate set of control variables, the Incan network can be considered to affect today's exports only through their correlation with the spatial distribution of new roads. Thus, such a network makes it possible to identify the effects of these new roads on firms' exports. The predicted export values are then used as an instrument for the actual change in exports in estimating the effect of these changes in exports on changes in employment conditioned by relevant covariates. Estimation results suggest that domestic road infrastructure has had a strong positive impact on exports and that this impact in fact did translate into employment generation. Specifically, the rate of growth of those exports carried over routes to main customs that were reduced in length due to the construction of new roads was 39.8 percent higher than the growth rate of exports traveling over routes whose length remained the same over the period 2003-2010. Further, infrastructure-driven exports in this period accounted for approximately 6.5 percent of the net new jobs associated with exports.

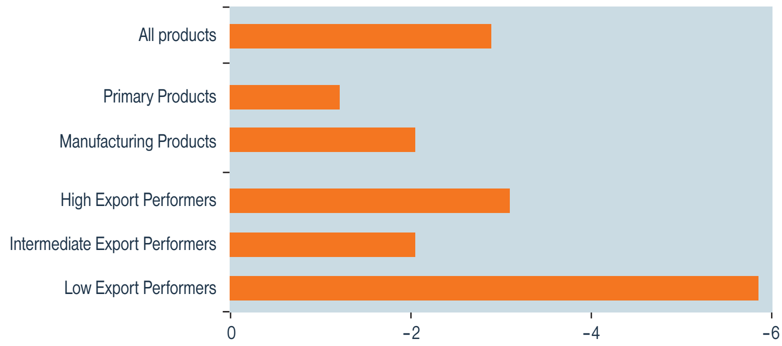
Here, export diversification is measured by the number of products exported as captured by the number of tariff lines at the 10-digit Harmonized System level that register positive exports.

The results obtained when estimating this relationship confirm that transport costs also have a significant impact on diversification, or what trade economists usually call *extensive margin* (see Figure 17 and Table B.5 in the Appendix). Estimates suggest that a 1 percent decline in average ad valorem transport costs would be associated with a 2.9 percent increase in the number of products exported. Given the diversification patterns in 2009, this implies that, on average, Ayacucho, Huancavelica, Huánuco, Loreto, San Martín, and Ucayali would see increases of 16, 7, 8, 42, 10, and 21, respectively, in the number of products they sell abroad as a result of a 10 percent reduction in these ad valorem transport costs.[15] The figures for Arequipa, Cusco, and Puno would be 193, 68, and 42, respectively. As expected, the impacts are larger for manufacturing goods and, interestingly, for less export-developed regions.

Regional Diversification: Domestic transport costs not only influence how much and what exporting regions already sell abroad, which has been the focus of the analysis so far. In addition, they can affect the abil-

[15] In interpreting the relatively small numbers, low initial levels should be taken into account.

FIGURE 17 ■ The Impact of Transport Costs on Product Diversification



Source: Authors' calculations based on data from MTC and SUNAT.
The figure presents the effect of domestic ad valorem transport costs on the number of products exported by each municipality based on a specification in which the dependent and main explanatory variables are expressed in natural logarithms, and which includes municipality-customs fixed effects and year fixed effects. Ad valorem transport costs are averaged across products. The classification proposed by the WTO is used to distinguish between primary and manufacturing products. Regions are grouped according to the above classification (see Figure 7). The sample period is 2001, 2003, 2005, and 2009.

ity of regions to participate in export markets altogether. In other words, these costs may not only have an impact on the extensive margin along the product dimension, but also along the regional dimension. This is not a minor issue for Peru, where only 350–500 out of 1,800 municipalities have exported over the period 2001–2009. Hence, we also assess the impact of transport costs on regional exports while explicitly taking this fact into account. More specifically, we examine whether and how much these costs matter for municipalities' export market participation.

The results, as reported in Table B.6 in the Technical Appendix B2, suggest that internal transport costs have a significant—although

Table 7 ■ Municipal Export Market Participation and Transport Costs: Baseline Estimating Equation

Determinants of Municipal Export Market Participation
Transport Costs between Municipality and Customs (–)
Permanent Municipality Specific Characteristics
Year-Specific Factors

Note: The expected sign of the estimated coefficient on the variable of interest appears between parentheses.

small—negative impact on export engagement: a 10 percent reduction in these costs would increase export probability by nearly 0.8 percent.[16]

How Much Would Lagging Regions Benefit from Better Infrastructure and Lower Transport Costs?

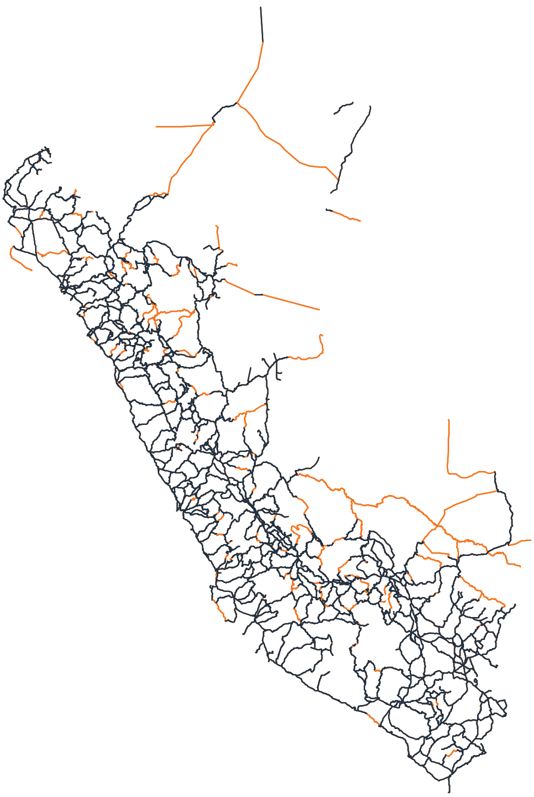
How much would less export-developed Peruvian regions increase exports as a result of infrastructure improvements that would reduce domestic transport costs? How much would overall and regional sectoral specialization change in response to this decline in transport costs? To answer these questions, we carry out a simple simulation exercise that examines the trade effects of a reduction in transport costs associated with a combination of interventions on the infrastructure—intensive margin (quality of existing roads) and the infrastructure—extensive margin (new roads). In the first case it is assumed that all existing routes will be paved. According to the most recent road inventory in Peru (MTC, 2011a), there are more than 2,000 kilometers of projected national roads, which amounts to some 10 percent of the total length of the national road network (see Figure 18). In our simulation, these and other projected departmental roads are assumed to be built and incorporated into the current route network as paved roads. Our benchmark scenario therefore assumes that all present roads are paved and that all planned roads are actually constructed.

Based on this scenario, we compute the implied change in per unit domestic transport costs and, using the results of the estimations discussed earlier, the associated change in municipal exports by products. These exports are then aggregated to obtain the respective variation in departmental export levels.[17] Even though the simulation results clearly cannot

[16] Note that because several municipalities do not trade at all, unit values are not observed and hence their ad valorem transport costs cannot be computed. In this regression, therefore, per unit transport costs are used instead as the main explanatory variable. Estimated coefficients presented in Table B.2 therefore measure the response to a different transport cost measure and accordingly are not comparable with those reported before (see Figure 12).

[17] Since we are particularly interested in the regional implications of infrastructure projects, we use the estimated effects obtained with the specification that allows for heterogeneous

FIGURE 18 ■ Projected Roads



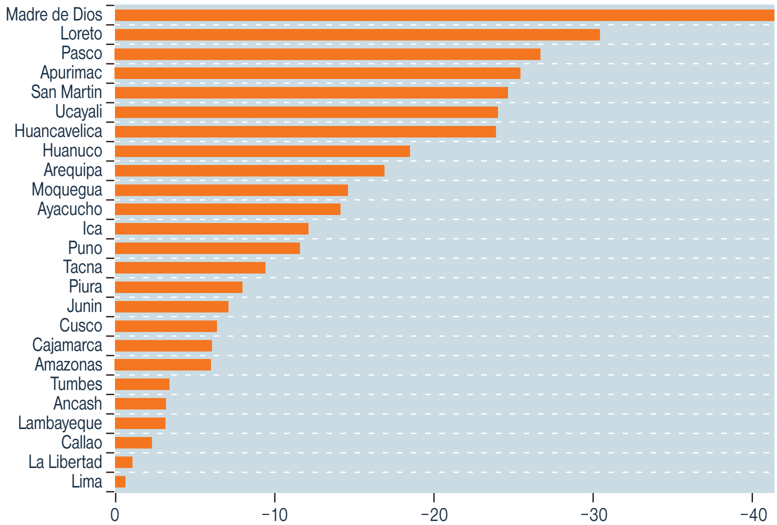
Source: Authors' elaboration based on data from MTC.
The map shows the current road network (black) and the projected roads (orange).

serve as social evaluations of these infrastructure projects, they do provide estimates of the portions of the direct benefits that are linked to trade.

Figure 19 shows the change in the internal ad valorem transport costs for each department between the baseline given by the levels in 2009 and those in the simulation scenario. Companies located in relatively

impacts across the groups of regions identified in the first part of this chapter. To compute the change in exports we compare the predicted values associated with these effects for 2009 with those simulated values that result from the assumption that domestic transport costs change as indicated above. Accordingly, in these exercises we assume that all other conditions, including the product unit values, remain as they were in 2009.

FIGURE 19 ■ Reduction in Transport Costs Associated with Simulated Infrastructure Improvement



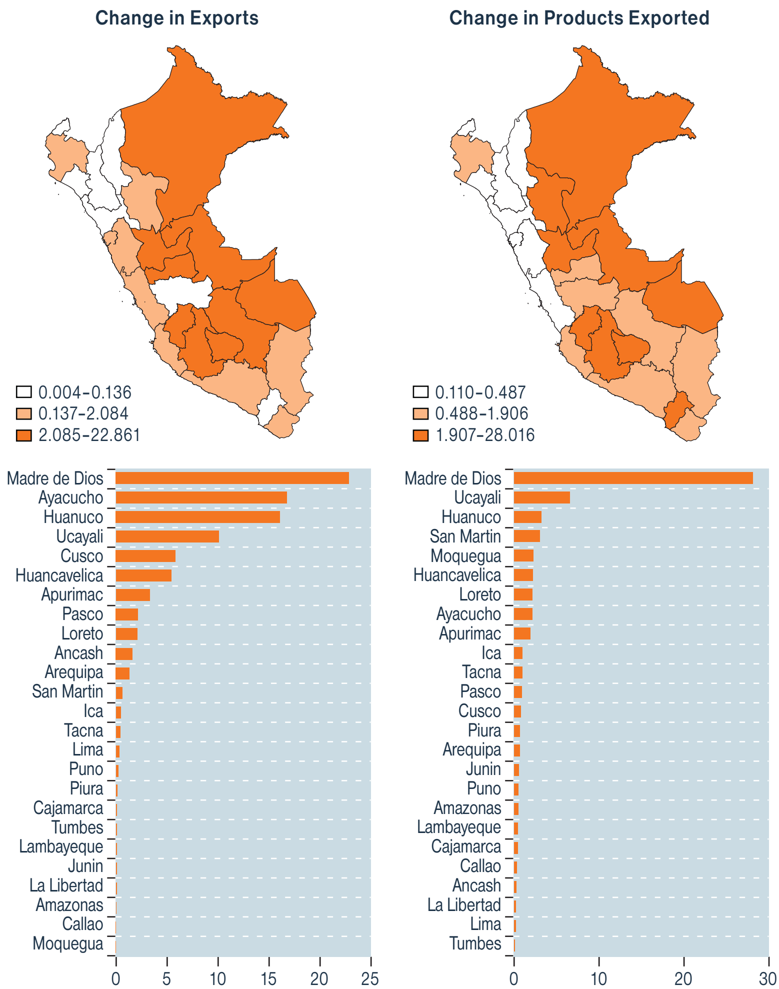
Source: Authors' calculations based on data from MTC.

The figures show the percentage reduction in average ad valorem transport costs under the assumption that all existing roads are paved and projected roads are built and paved. The benchmark is 2009; product unit values are assumed to remain as they were in this year.

export-developed regions such as Lima are already well connected to their relevant customs and use mostly paved routes. Therefore, these companies would see no significant change in the transport costs they face. In contrast, those firms located in less-export developed departments, such as Huancavelica, Loreto, Ucayali, and particularly Madre de Dios, would experience a substantial reduction in transport costs as a result of paving existing roads and building new paved roads. What would such a reduction imply in terms of foreign sales?

As shown in Figure 20, six out of the nine regions among those in the less export-developed group would be the top beneficiaries in terms of increased total exports resulting from infrastructure improvements, and eight of the nine regions appear in the first half of the ranking. In this group of departments, exports would increase on average by 12.8 percent; Madre de Dios, Ayacucho, Huánuco, and Ucayali would register expansions in total exports of 22.9 percent, 16.8 percent, 16.1 percent, and 10.1 percent,

FIGURE 20 ■ Response of Regional Exports to Reduced Transport Costs



Source: Authors' calculations based on data from MTC and SUNAT.

The maps and figures present the percentage change in total departmental exports and number of products exported associated with the reduction in transport costs shown in Figure 19. The results are computed using the estimation results from specifications including municipality-customs-product fixed effects and year fixed effects, and municipality-customs fixed effects and year fixed effects, respectively, and allowing for heterogeneous effects across groups of regions. The simulation assumes that all routes are paved and projected roads are built and paved. Regions are grouped according to the above classification (see Figure 7). The benchmark is 2009, so all other conditions, including the product unit values, are assumed to remain as they were in that year.

respectively. These expansions would be primarily driven by larger foreign sales of their main exporting sectors: wood products (46.5 percent); ores, slag, and ash (24.5 percent); ores, slag, and ash (20.1 percent); and wood products (10.2 percent), respectively.

Some departments in the less export-developed group would also obtain non-negligible gains in terms of the number of products sold abroad. This is particularly the case with Madre de Dios, whose export basket would expand by almost 30 percent. Ucayali would increase its set of export products by more than 5 percent.

At the other extreme of the distribution, the more export-developed departments, such as Callao and Lima, whose firms already face relatively low transport costs, would barely see a change in their export levels or degrees of product diversification as a consequence of road improvement projects.

In considering the previous figures, it should be kept in mind that projected paving and road construction projects are distributed unevenly over space. Clearly, exports from some less export-developed regions would increase significantly more if they received the same infrastructure investment that their most benefited peers in the group receive. Thus, for instance, total exports from Ucayali would expand by almost 17 percent and the number of products that the department's firms sell in international markets would rise more than 10 percent if transport costs there were reduced like in Madre de Dios.

In short, paving roads and building new roads would enhance trade outcomes along the intensive and extensive margins, essentially for lagging regions.

The Policy Agenda Ahead

Export outcomes are markedly heterogeneous across Peru's regions. The export performance of top performing departments such as Callao and Lima contrast sharply with their lagging counterparts Ayacucho, Amazonas, Huancavelica, Huánuco, Madre de Dios, San Martín, and Ucayali. Domestic road infrastructure and hence domestic transport costs play an important role in explaining these trade outcomes and their spatial patterns. Higher transport costs translate into lower export levels, lower degree of product diversification, and fewer regions and subregions participating in international markets. Thus, a 1 percent decrease in ad valorem transport costs would result in an average increase of more than 4 percent in product level exports and of almost 3 percent in the number of products exported.

Infrastructure that reduces transport costs can therefore be instrumental for spreading the benefits of privileged market access associated with trade agreements Peru has signed in recent years. For instance, paving all relevant routes and building projected roads would make it possible for less export-developed departments such as Madre de Dios, Ayacucho, and Huánuco to expand their total exports by more than 16 percent while helping these departments to diversify their export bases. In contrast, gains from such roads projects would be substantially less for more advanced regions such as Callao and Lima, which would expand their total exports and number of products sold abroad by less than 1 percent. Note that these effects could be expected to prevail over the short to medium term and therefore should be viewed as a lower bound. Over time, general equilibrium impacts (on production, for example), which are not factored in and would predictably act in the same direction, would build up.[18]

Upgrading and expanding the road network to help create conditions for more balanced regional export patterns would require the mobilization of substantial amounts of resources. A recent study suggests that, despite the progress made in recent years, Peru has an investment gap in road infrastructure of approximately 6 percent of GDP in relation to demand associated with projected population and economic activity until 2018 (see IPE, 2009).

Such infrastructure investments can remain productive over long time periods, and accordingly yield large benefits—but only if they are adequately maintained. Despite recent signs of improvement, there has

[18] It should be taken into account that improved infrastructure may also lead to increased import penetration, thus potentially negatively affecting production of less competitive firms. On the other hand, it should not be forgotten that lower transport costs facilitate access to relevant imported inputs and thereby may favor the production of certain goods.

historically been a marked deficit in road maintenance in the country. Only 12.5 percent of Peru's road network received permanent maintenance in the early 2000s (see IPE, 2009). Interventions on this network have primarily taken the form of rehabilitation of roads that had already deteriorated (see MTC, 2007b). Thus, over the period 1999–2006, the budget allocated for restoration or reconstruction was three times larger than that for maintenance, and execution of these resources was poor (see IPE, 2008). Neglecting maintenance appears to have been very costly. Estimates indicate that US$718 million invested in restoring 1,357 kilometers of road networks between 1992 and 2005 were lost as the roads subsequently deteriorated to the point that their condition became regular, bad, or very bad. These losses could have been avoided by investing only US$98 million in routine (annual) and periodic (every five years) maintenance (see IPE, 2008).

Needless to say, proper connectivity between road transportation and other transport modes is also a fundamental component of an efficient transport system.[19] This is particularly important for departments in the Selva region, which has more than 6,000 kilometers of navigable rivers (see MTC, 2001). Nevertheless, modal infrastructures are still largely unconnected. This, in addition to the absence of appropriate norms and policies, has made it difficult for multimodal transport services to develop (see MTC, 2007b).

The multimodality problem shows that hardware infrastructure is certainly not the only factor important in developing an effective transportation system. Although institutions and policies are not the focus of this chapter, they also matter greatly. The MTC, through the Under-Ministry of Transportation, is the public sector entity responsible for implementing and maintaining the national, departmental, and rural road infrastructure in collaboration with the regional and local governments, as well as for planning, coordinating, executing, and regulating actions aimed at ensuring efficient and safe transport services at the national level. Even though the MTC undoubtedly has specific strengths, its weaknesses prevent it

[19] Unfortunately, we were not able to incorporate these other modes into our analysis because we could not get access to the respective georeferenced information and cost data.

from adequately carrying out these functions, among them the following: limited institutional development; weak auditing, control, and enforcement capabilities; insufficient funding and capacity to engage the private sector in the development and management of transport infrastructure and services; and personnel compensation and promotion policies that do not create the right incentives due to legal constraints (see MTC, 2006). At the same time, regional and local governments have acquired increased responsibilities in transport issues in recent years as a result of the ongoing decentralization process (see MTC, 2011b).[20] Regional governments now formulate the sectoral policy in their territories, administer the regional road infrastructure, and enforce norms (see OPP, 2011). However, these subnational counterparts also show organizational and management deficiencies, which are heterogeneous across regions (see MTC, 2008). In the end, effective coordination across different levels of government levels and dealing satisfactorily with asymmetric institutional abilities that could hinder a more even spatial development are important challenges in this area.

As for the policies, the need for improved regulations is critical. Peru liberalized and deregulated freight transportation services in the 1990s. This stimulated the expansion of freight transportation as well as intensified competition. However, at the same time the absence of concomitant measures (lack of regulation regarding the conditions and requirements for service provision and virtual inexistence of controls) generated a series of unintended negative consequences, including excess supply, service atomization (freight companies have an average of just 2.6 trucks each), a large degree of informality, and an old truck fleet (nearly 50 percent of the fleet is older than 15 years), which has resulted in unfair competition and safety problems (see MTC, 2007 and MTC, 2010). These safety problems are acute in Peru as attested by the annual occurrence of more than 70,000 road accidents and the deaths of more than 3,000 persons in these accidents (see CNSV, 2007). In recent years, the public sector took steps to improve this situation by implementing formality controls on transport companies. Figure 21 presents the regional distribution of registered firms and their

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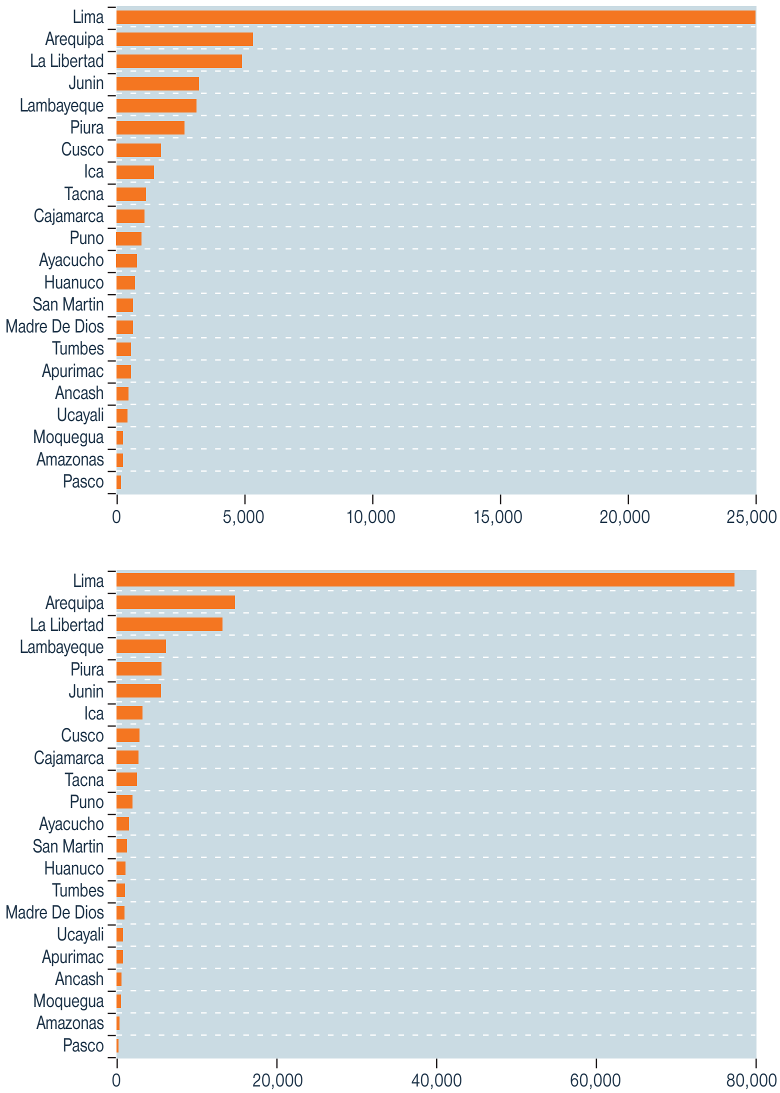
[20] MTC (2011b) presents a detailed report on the degree of progress of the decentralization process in the transport sector.

FIGURE 21 ■ Spatial Distribution of Registered Freight Companies and Their Fleets



Source: Authors' elaboration based on data from MTC.
The figure shows the number of freight companies (top) and the number of vehicles registered in each department (bottom) as of 2010. Companies and vehicles in Callao are included in Lima. Data for Huancavelica and Loreto

fleets as of 2010, which shows both an extreme geographical concentration along with a more pronounced atomization problem in non-coastal departments such as Amazonas, Huánuco, and Ucayali. While progress has been made, much remains to be improved in this area.

A second major policy change in the 1990s was the launching of a program of road concessions begun in 1994 when Peru contracted out a road project between Arequipa and Matarani. Currently, 14 active road concessions account for a total of 5,363 kilometers of roads, which is more than 20 percent of the total length of national routes.[21] These concessions are primarily based on building, operational, and transfer contracts in which private firms build and finance an infrastructure project and then charge for the use of the road over a given period; after this period, the work is transferred to the public sector. The US$3,423 million committed for investments through this program will help close the country's infrastructure investment gap. In addition, evidence indicates that traffic has increased and travel times have declined significantly. Despite these gains, concessions have not been free of problems. In some cases there have been substantial delays in handing over the lands to the private companies that will carry out the construction work. In other cases, toll increases have been triggered by fixed dates even though the actual infrastructure improvements that would justify them have not been carried out (see Mendiola et al., 2011). In addition, several contracts had to be renegotiated due to inappropriate risk allocation (see Zevallos, 2008). Besides the MTC as the public sector concessor, two main institutional actors participate in the process: PROINVERSIÓN, a public agency that promotes private investment and which designs the concession contracts and carries out the bidding process; and OSITRAN, which regulates the concessionaires and oversees the fulfillment of the concession contracts.[22]

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[21] For further details on the concession program see MTC (2012).

[22] The advisory board of PROINVERSIÓN is composed of the minister of economy and finance, the minister of transport and communications, the minister of energy and mines, the minister of housing, construction, and sanitation, and the minister of agriculture. The advisory board of OSITRAN has five members appointed by the president of the Ministers' Council, the minister of economy and finance, and the minister of the sector pertaining to the regulated activity.

Each of these entities is responsible for one specific step in the concession process, and there is no formal provision for sharing information among them. For example, the experience of OSITRAN in administering the contracts has not been used to design the bidding processes or in the contracts themselves to help minimize the need for amendments.

Last, but definitely not least, given the existence of strong policy complementarities, infrastructure will be more effective in fostering exports if it is properly combined with additional policies that reduce other trade costs. This is particularly true in the case of trade facilitation and export promotion actions that address obstacles to completing administrative and logistic processes and gathering the information required to operate in international markets (see Volpe Martincus and Carballo, 2008 and Volpe Martincus et al., 2013b). Thus, building a new route may be worthless in terms of additional trade if the time it saves is subsequently lost in dealing with customs procedures or port operations. Similarly, for such a route to actually lead to exports of new, locally produced goods, it is necessary to know where to export them (where the demand is) and how to meet the standards of these potential markets (how the demand profiles look). PROMPERU has opened five regional export promotion offices in Chiclayo (Lambayeque), Iquitos (Loreto), Huanayo (Junín), Cusco (Cusco), and Arequipa (Arequipa). These offices provide local companies with basic training and general information on the export process and foreign markets. They establish links with local public offices, business associations, and other entities to promote export initiatives with programs similar to those carried out at headquarters. In addition, PROMPERU has ten regional information centers in Ayacucho, Cajamarca, Huánuco, Ica, La Libertad, Madre de Dios, Piura, Puno, San Martín, and Tacna. These centers provide information on marketing, prices of products with overseas demand, profiles of products with greater demand abroad, and export procedures and tax regimes; they also organize training activities (see Volpe Martincus, 2010).

Technical Appendix

Appendix A – Estimation of Transport Costs

Transport costs are calculated following the methodology proposed by Combes and Lafourcade (2005), which is based on a Geographic Information System (GIS). This system consists of a digitalized real transport network that connects the country's municipalities with each other, including those where customs (e.g., ports) are located. The network is composed of several arcs that correspond to the different types of roads in the road system (highways, primary roads, and secondary roads).

In order to identify the lowest cost itinerary between a municipality and an exit point, we use the Arc View program. Here we assume that along a specific arc there are two kinds of costs associated with the transportation of a good: distance-related costs and time-related costs. The former are primarily expenses for fuel, tire renewing, lubricants and filter changes, maintenance, and tolls; the latter are linked to wages, insurance, depreciation, and taxes, and other expenses (see Table A1).

Table A.1 ■ Distance- and Time-Related Costs

Transport Cost Components					
Cost and Components\Year		**2001**	**2003**	**2005**	**2009**
Distance	Fuel	0.1929	0.2217	0.3076	0.3805
	Tire	0.0908	0.0477	0.0845	0.0928
	Lubricants and Filters	0.0076	0.0065	0.0093	0.0093
	Maintenance	0.0189	0.0217	0.0301	0.0372
	Toll	0.0426	0.0576	0.0752	0.0979
Time	Wage	0.1261	0.1212	0.1434	0.1884
	Depreciation	0.1432	0.1135	0.1068	0.1125
	Insurance	0.0375	0.0356	0.0529	0.0536
	Taxes	0.0578	0.0452	0.0449	0.0447
	Other Expenses	0.1414	0.1367	0.1672	0.1489

Source: Advanced Logistics Group (2009).
Note: Figures are in US dollars

Hence, the total costs are:

$$C_{jlt}^{Total} = \left\{ \begin{array}{l} \Sigma_{a\varepsilon I_{jlt}} [(fuel_t + tire_t + lubricants\ and\ filters_t \\ \quad + maintenance_t + toll_t) + (wage_t \\ \quad + depreciation_t + insurance_t + taxes_t \\ \quad + other\ expenses_t)]d_a \end{array} \right\} \tag{A1}$$

where d_a denotes the distance between the end-nodes of an arc a; j is the municipality of origin; l is the exiting customs (port, airport, or border); t is time; and I_{jtl} is the itinerary used to transport the good from j to l. Note that we have already expressed the time-related costs in terms of kilometers by dividing each component by the relevant speed. If Γ_{jlt} represents the set of itineraries that a truck can use to join the place of production j and the exiting customs l, then the cost of shipping a ton of the good in question corresponding to the lowest cost itinerary is given by:

$$C_{jlt}^{Total^{Min}} = \min_{I_{jlt}\,\varepsilon\Gamma_{jlt}} \left\{ C_{ijt}^{Total} \right\} \tag{A2}$$

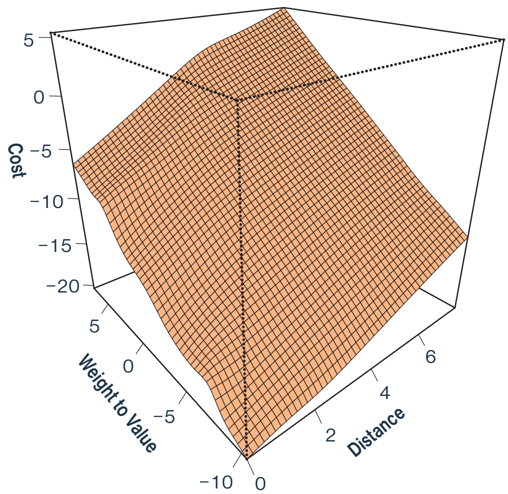
As mentioned in the introduction to this chapter, Peru has three natural geographical regions characterized by altitude and climate: Costa, Sierra, and Selva. The gradients of these natural regions are: 0–3 percent, 5–7 percent, and 3–5 percent, respectively. In addition, roads can be categorized as paved and non-paved. Roughness, elevation of the terrain, and the type of surface of the roads affect vehicle travel times, maintenance costs, fuel consumption, and depreciation. We accordingly correct per unit costs using the following coefficients of adjustment provided by the MTC:

Table A.2 ■ Coefficients of Adjustment

Region\Road Surface	Paved	Non-Paved
Costa	1.0	2.2
Selva	1.2	2.9
Sierra	1.4	3.9

Source: MTC (2002)

FIGURE A.1 ■ Distance, Weight to Value Ratio, and Ad Valorem Transport Costs



Source: Authors' elaboration based on data from MTC and SUNAT.
The 3D plot shows the relationship between the (natural logarithm of the) distance to the main customs, the (natural logarithm of the simple) average weight to value ratio, and the (natural logarithm of the simple) average ad valorem transport cost to the main customs. Data correspond to 2009.

Finally, from Equation (A2), we can express ad valorem transport cost of good k from municipality j to customs l as follows:

$$\tau_{jlkt} = \frac{C_{jlt}^{Total^{Min}}}{\Theta} \frac{Weight_{jlkt}}{Value_{jlkt}} \tag{A3}$$

where Θ is the capacity of the truck; and $Weight_{jlkt}$ and $Value_{jlkt}$ are the weight and value of the exports of good k from municipality j through customs l. Ad valorem transport costs consistently increase with the distance and the weight to value ratio (see Figure A1).

Appendix B – Empirical Assessment

B1 Estimating Equations and Methods

Table B.1 ■ Estimating Equations and Methods

Export Outcome	Municipal Exports per Product and Customs	
Estimating Equation	$lnX_{jlkt} = \alpha ln(1+\tau_{jlkt}) + \gamma_{jlk} + p_t + \varepsilon_{jlkt}$	(A4)
Estimation Method	Least Squares, Fixed Effect Panel	
Export Outcome	Municipal Exports per Product and Customs, Distinguishing Across Product Categories/Region Groups	
Estimating Equation	$lnX_{jlkt} = \Sigma_z \alpha^z ln(1+\tau_{jlkt}) + \gamma_{jlk} + p_t + \varepsilon_{jlkt}$	(A4')
Estimation Method	Least Squares, Fixed Effect Panel	
Export Outcome	Number of Products Exported by Municipality per Customs	
Estimating Equation	$lnN^K_{jlt} = \beta ln(1+\overline{\tau_{jlkt}}) + \varphi_{jl} + \theta_t + \mu_{jlt}$	(A5)
Estimation Method	Least Squares, Fixed Effect Panel	
Export Outcome	Number of Products Exported by Municipality per Customs Across Product Categories	
Estimating Equation	$lnN^K_{jlt} = \beta^z ln(1+\overline{\tau_{jlkt}}) + \varphi^z_{jl} + \theta^z_t + \mu^z_{jlt}$	(A5')
Estimation Method	Least Squares, Fixed Effect Panel	
Export Outcome	Number of Products Exported by Municipality per Customs Across Region Groups	
Estimating Equation	$lnN^K_{jlt} = \Sigma_z \beta^z ln(1+\overline{\tau_{jlkt}}) + \varphi_{jl} + \theta_t + \mu_{jlt}$	(A5")
Estimation Method	Least Squares, Fixed Effect Panel	
Export Outcome	Binary Indicator that Takes the Value of One if the Municipality Exports and Zero Otherwise	
Estimating Equation	$\eta_{jt} = \delta ln\left(\frac{\overline{C^{Total\,Min}_{jlt}}}{\Theta}\right) + \varsigma_j + \phi_t + \xi_{jt}$	(A6)
Estimation Method	Least Squares, Fixed Effect Panel, and Conditional Logit	

Source: Authors' elaboration.

where X denotes for exports, N^x the number of products, z product category/region group. The sample years are 2001, 2003, 2005, and 2009.

B2 Estimation Results

Table B.2 ■ The Impact of Transport Costs on Municipal Exports per Product

Ad Valorem Transport Cost	-4.699***	-4.680***	-4.602***	-4.311***	-4.313***	-4.573***	-4.262***	-4.253***
	(0.831)	(0.845)	(0.825)	(0.728)	(0.737)	(0.834)	(0.722)	(0.729)
Municipality-Customs-Product Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality-Year Fixed Effects	Yes	Yes	No	Yes	Yes	No	No	No
Customs-Year Fixed Effects	Yes	No	Yes	Yes	No	No	Yes	No
Product-Year Fixed Effects	Yes	Yes	Yes	No	No	Yes	No	No
Year Fixed Effects	No	No	No	No	No	No	No	Yes
Observations	97,855	97,855	97,855	97,855	97,855	97,855	97,855	97,855

Source: Authors' calculations based on data from MTC and SUNAT.

The table reports the LS estimates of alternative specifications of Equation (A4) for the years 2001, 2003, 2005, and 2009. The dependent variable is the natural logarithm of municipal exports per product and customs. Ad valorem transport costs are computed as explained in this Appendix and are also expressed in natural logarithms. Fixed effects are included but not reported. Robust standard errors are in parentheses below the estimated coefficients. * significant at 10 percent; ** significant at 5 percent; and *** significant at 1 percent.

Table B.3 ■ The Impact of Transport Costs on Municipal Exports per Product

Alternative Standard Errors	
Ad Valorem Transport Cost	–4.253
Heteroskedasticity-Consistent	(0.729)***
Clustered by Municipality-Customs-Product (Serial Correlation Consistent)	(1.006)***
Clustered by Sector, 2-Digit HS	(0.943)***
Clustered by Sector, 1-Digit HS	(0.965)***
Clustered by Province	(0.639)***
Clustered by Department	(0.670)***
Clustered by Province-Sector, 2-Digit HS	(1.020)***
Clustered by Department, 1-Digit HS	(0.917)***
Municipality-Customs-Product Fixed Effects	Yes
Year Fixed Effects	Yes
Observations	97,855

Source: Authors' calculations based on data from MTC and SUNAT.

The table reports the LS estimates of Equation (A4) with alternative standard errors for the years 2001, 2003, 2005, and 2009. The dependent variable is the natural logarithm of municipal exports per product and customs. Ad valorem transport costs are computed as explained in this Appendix and are also expressed in natural logarithms. Municipality-customs-product and year fixed effects are included but not reported. Robust standard errors are in parentheses below the estimated coefficients. * significant at 10 percent; ** significant at 5 percent; and *** significant at 1 percent.

Table B.4 ■ The Impact of Transport Costs on Municipal Exports per Product across Categories

Product Classifications	
Primary Products	–4.632*** (1.479)
Manufacturing Products	–4.045*** (0.847)
Regional Classification	
High Export Performers	–4.403*** (0.966)
Intermediate Export Performers	–3.822*** (0.791)
Low Export Performers	–7.935* (4.074)
Municipality-Customs-Product Fixed Effects	Yes
Year Fixed Effects	Yes
Observations	97,855

Source: Authors' calculations based on data from MTC and SUNAT.

The table reports the LS estimates of Equation (A4') for the years 2001, 2003, 2005, and 2009. The dependent variable is the natural logarithm of municipal exports per product and customs. Ad valorem transport costs are computed as explained in this Appendix and are also expressed in natural logarithms. In the first panel the effect of transport costs is allowed to differ for primary goods and manufacturing goods. These categories are defined using the classification proposed by the WTO. In the second panel the effect of transport costs is allowed to differ across the groups of regions identified above (see Figure 7). Municipality-customs-product and year fixed effects are included but not reported. Robust standard errors are in parentheses below the estimated coefficients. * significant at 10 percent; ** significant at 5 percent; and *** significant at 1 percent.

Table B.5 ■ The Impact of Transport Costs on Municipal Export Extensive Margin

All Products and Regions	−2.893*** (0.544)
Product Classification	
Primary Products	−1.221*** (0.376)
Manufacturing Products	−2.054** (0.803)
Regional Classification	
High Export Performers	−3.101*** (0.723)
Intermediate Export Performers	−2.056** (0.838)
Low Export Performers	−5.844* (3.422)
Municipality-Customs Fixed Effects	Yes
Year Fixed Effects	Yes
Observations	2,543

Source: Authors' calculations based on data from MTC and SUNAT.

The table reports the LS estimates of Equations (A5), (A5'), and (A5'') for the years 2001, 2003, 2005, and 2009. The dependent variable is the natural logarithm of the number of products exported by each municipality through the different customs. Ad valorem transport costs are computed as explained in this Appendix and are expressed as the natural logarithm of their simple average across products. In the second panel the effect of transport costs is allowed to differ for primary goods and manufacturing goods. These categories are defined using the classification proposed by the WTO. In the third panel the effect of transport costs is allowed to differ across the groups of regions identified above (Figure 7). Municipality-customs and year fixed effects are included but not reported. Robust standard errors are in parentheses below the estimated coefficients. * significant at 10 percent; ** significant at 5 percent; and *** significant at 1 percent.

Table B.6 ■ The Impact of Transport Costs on Municipal Export Market Participation

	Fixed Effects	Conditional Logit
Average Transport Costs	−0.0854*** (0.0125)	−0.797*** (0.156)
Municipality Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	7,150	7,150

Source: Authors' calculations based on data from MTC and SUNAT.

The table reports the LS and Conditional Logit estimates of Equation (A6) for the years 2001, 2003, 2005, and 2009. The dependent variable is a binary indicator that takes the value of one if the municipality exports, and zero otherwise. Per unit transport costs are computed as explained in this Appendix and are expressed as the natural logarithm of their simple average across customs. Municipality and year fixed effects included but not reported. Robust standard errors are in parentheses below the estimated coefficients. * significant at 10 percent; ** significant at 5 percent; and *** significant at 1 percent.

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“This book, using modern technique, reports the potential social returns accruing from greater, and integrated, investment in internal transportation. Latin America put its faith in highways in post World War II emphasis upon import substitution and domestic industrialization. Railroads and development of port facilities were secondary. Now, with demonstrated primary sector export capability over the last decade, it is not too late to remedy this error, and by so doing, to attack the high internal degree of income inequality found in most countries. Policy matters, and this coherent IDB study hopefully will have a positive influence on national decisions”.

Albert Fishlow, Professor Emeritus at both University of California, Berkeley and Columbia University. Former Paul Volcker Chair in International Economics at the Council of Foreign Relations.

“This study greatly advances our knowledge of the impact of domestic transport costs on trade performance and the regional distribution of export production. It is an outstanding example of readable, rigorous research that generates important policy insights. I hope it will be read and acted upon by Latin American policymakers, and that it will stimulate similar data collection efforts in other regions, thereby filling an important gap in our understanding of trade costs”.

Bernard Hoekman, Director, Global Economics Program, European University Institute and former Director, International Trade Department , World Bank.

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