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Abstract

A growing literature has begun to focus on the empirical relationship between transportation costs and international trade flows. This survey will document some of the most important recent trends in this literature, including a burgeoning focus on frictions at the border (such as customs procedures and port quality) as well as those behind-the-border (e.g. domestic infrastructure and regulatory quality). These empirical analyses have become possible because of the development of a number of new data sets, especially from World Bank initiatives. This new focus is particularly welcome for two reasons. Firstly, falling formal trade barriers from past negotiations means that transportation costs have more relative importance for trade. Secondly, stalled multilateral trade negotiations means that some of the most important sources of trade integration benefits may come from "trade facilitation," especially in developing countries.

Transportation costs often have been an afterthought for international trade economists and analysts both in academia and in the policy world. This is a curious fact given that transportation costs have taken on a more important relative role in influencing trade as traditional interventions such as tariffs and export subsidies have fallen. This chapter will provide a brief overview of some of the recent empirical work that documents the determinants of trade-relevant transportation costs and the subsequent impact on goods trade flows. Much of the literature surveyed here has been undertaken by trade economists so that the approaches reflect a heavy reliance on gravity equations.

We will see that a paucity of data has been a major impediment to formal analysis in the past; there were no consistent and comparable measures of transportation costs across countries available to researchers. Recent efforts by the World Bank and others have helped fill some of these holes and allowed for a much more detailed understanding of how transport costs (some at the border and others behind-the-border) can affect trade flows. More emphasis on issues related to transportation costs in trade negotiations at the multilateral and regional level (especially in transportation services) also has brought some of the related issues to the forefront. The combination of improved data and policy exigencies likely will encourage more research in the future.

One notable aspect of this review is there has been relatively little empirical work focused on the *firm-level* nexus of trade and transportation costs. This stands in sharp contrast to recent work by economists on firm-level and transaction-level trade outcomes. Meltiz (2003) helped spawn an avalanche of work on how the assumption of firms with heterogeneous productivities combined with fixed costs of exporting can have a critical impact on the pattern and consequences of increased trade. These fixed costs in turn are clearly associated with border barriers that are part of a broad definition of transporting goods internationally from factory to consumer.

Theoretical trade economists also have considered transportation costs something of a sideshow. This may reflect a view that transportation costs are a kind of "natural" barrier; distant countries simply are less likely to trade because it is expensive to move goods over long distances. Traditional trade models (e.g. Ricardian and Hecksher-Ohlin models) are silent on transportation costs. To the extent that transportation costs were modeled, they often came in the form of Samuelson (1954) "iceberg" trade costs, whereby a fixed fraction of the good is "lost" as it moves from the exporting country to the importing country.[1]

This lack of focus on the role of transportation costs among trade analysts is somewhat puzzling for at least two reasons. On the one hand, economic historians have pointed to the dramatic fall in shipping costs with the advent of the steamship as a major contributor to the rapid economic globalization of the 19th century. As we will see, the container revolution and jet aircraft have contributed in recent decades to an ever greater level of economic integration. Moreover, as Finger and Yeats (1976) recognized long ago, the relative importance of transport cost has increased in the era of multilateral trade liberalization. Tariffs and traditional import restrictions have fallen dramatically in recent years so that many of the remaining barriers reflect various types of frictions, including domestic and international transportation costs.

Policy aimed at reducing transportation barriers has not developed to the extent to which tariffs have been liberalized. There has been some recent movement in this direction. Most notably, the 2015 Trade Facilitation Agreement under the aegis of the World Trade Organization increased efforts to reduce customs administration and other border costs, especially in developing countries.[2] But the existing literature on trade facilitation also is generally silent on the *costs* of implementing reforms

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[1] For example, Krugman (1991) and Brander and Krugman (1983) incorporate iceberg transportation costs into a model of economic geography and reciprocal dumping, respectively.

[2] We will discuss empirical studies relevant to the Trade Facilitation Agreement later in the chapter.

that lower transportation costs, which means that the *net* welfare effects of reforms are largely unknown.

The practical importance of understanding the effects of reforms that lower transportation costs is clear. Behar and Venables (2011) and Hummels (2007) provide extremely useful surveys in which they argue that the reduction in transportation costs (through container shipping and air cargo services) has been critical to the development of just-in-time manufacturing, vertically fragmented production processes, and global supply chains. Thus, while trade agreements may have moved slowly to embed transportation disciplines within international trade agreements, commercial interests have moved aggressively forward in building networks based on lower transaction and transportation costs.

The rest of the chapter is organized in the following way. Section II will lay out a conceptual framework of transportation costs including the trade policy context. Section III will outline some of the methodological and data issues surrounding empirical analysis of these issues. In Section IV we will turn to studies about the determinants and impact of transportation costs on trade, with a particular focus on studies related to "trade facilitation."[3] Section V provides a brief discussion about the policy relevance of these studies while the final section offers some concluding thoughts as well as areas for future research.

Section II. Setting the Stage

A narrow view of transportation costs in the international trade context might focus exclusively on outlays for movement of goods from an exporting country's port-of-departure to an importing country's port-of-entry. This interpretation would emphasize what might affect the costs of international movement of goods by ships, aircraft, trucks, or rail. But the commercial reality is that a whole range of concerns can affect the costs of moving a good from a factory to a final consumer. For example, customs and bureaucratic procedures at the border can increase delays of moving goods onto ships and planes destined for final markets. Many countries limit the ability of foreign airlines to operate freely within a domestic market. Others might restrict foreign investment in transportation infrastructure like ports or port services. Some nations have antiquated internal transportation systems that can dramatically complicate moving goods to a port for export.

Figure 1 depicts various links that will act as a framework for this chapter. Link 1 represents the movement of goods from the factory to the border of the exporting country. The costs of doing so will reflect the domestic transportation infrastructure, logistics, and the regulatory environment. Link 2 reflects processing of goods for exports at the border; they must pass through customs and be loaded onto the mode of transportation used to move the good to the importing country border. Link 3 is the "traditional" view of transportation costs in trade; i.e., the physical movement of goods from one port to another. Links 4 and 5 are the foreign analogs to Links 1 and 2: goods must pass through customs and then move to the final consumer. A further complication is that firms engaged in trade potentially can choose among various modes of transportation (e.g. air vs. sea), and policies chosen by governments can affect the attractiveness of one transportation mode relative to another. Since transportation activities are typically services, new initiatives to liberalize services take on particular importance in this context.

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[3] This chapter will not cover important relevant issues such as digital trade and policies towards e-commerce and Internet services more broadly.

Figure 1
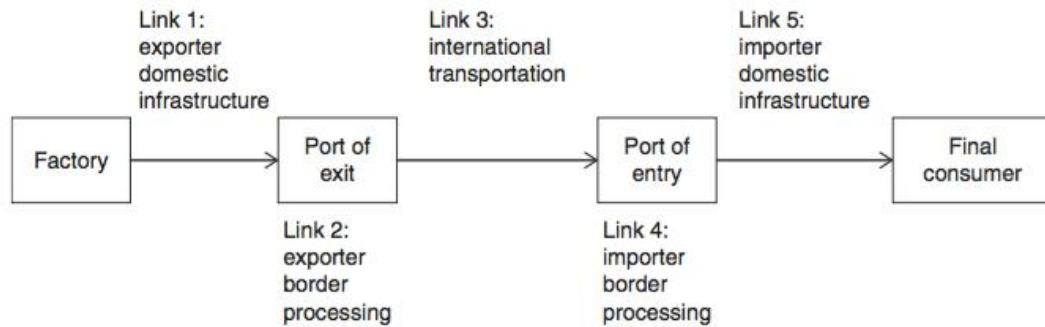
This more complicated view of transportation greatly increases the scope for analysis. For example, while standard trade policy may affect the Link 3, a host of policies can affect the costs at the border and the costs of moving the goods to and from ports inside the domestic economy. Indeed, we will see below that the Trade Facilitation Agreement is properly thought of in the context of Links 2 and 4.

The costs associated with these links can be affected by physical realities such as geographical isolation and distance. But transport frictions also reflect policy decisions taken by governments that can be affected by international trade agreements, as well as decisions taken purely domestically. Before proceeding, it is therefore worth noting the extant multilateral trade commitments that are most relevant for transportation costs.

These new disciplines are less about border-to-border and behind-the-border transactions and more about what happens at the border itself (i.e. Links 2 and 4). They also represent a relatively low level of ambition in terms of reducing the costs of moving goods from factories, through borders, and to final customers.

Article V of the GATT includes commitments on the non-discriminatory treatment of goods in the customs clearance process, with specific attention to goods in transit. WTO members also have agreed to transparent and non-discriminatory customs valuation of goods in Article VII of the GATT. Article VIII requires that all fees charged for importation and exportation of goods reflect the approximate costs of those services. Finally, Article X requires that Member States' trade rules and regulations be "published promptly." Nonetheless, there has been remarkably little progress on extending multilateral disciplines within the GATT system in sectors such as maritime transportation and air cargo services.

More recently, the focus has turned to a broader set of issues broadly under the rubric of "trade facilitation," which lies directly at the intersection of trade and transportation cost. For example, the 1996 WTO Ministerial in Singapore established a permanent working group on trade facilitation in anticipation of improving the functioning of customs procedures and goods trade processing (Fergusson (2008)).[4] Indeed, the Trade Facilitation Agreement (TFA) concluded in December 2015 is the only concrete major outcome so far that has come out of the Doha Development Round launched in 2002.

Economists at international development agencies have produced a wealth of research on topics that touch on trade facilitation, partly in anticipation of this agreement, but also involving a broader set of issues. Perhaps surprisingly, there is no broadly accepted definition of trade facilitation. A narrow characterization of trade facilitation would include only areas such as customs rules, border procedures, and port-of-entry infrastructure, corresponding to Links 2 and 4 in Figure 1. A broader definition of trade facilitation would include all domestic and border systems and procedures that can

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[4]   Other "Singapore Issues" included government procurement, trade and investment, and trade and competition. No consensus on these issues has been found in WTO negotiations.

help move goods and services into and out of a country. This view would consider improvements in items such as domestic logistics, internal infrastructure, and regulatory environment as all part of trade facilitation. This definition also would include Links 1 and 5 into this more expansive view of trade facilitation.

Despite the successful conclusion of the TFA noted above, progress on multilateral liberalization has stalled in recent years. Negotiation focus has turned instead towards bilateral and regional trade agreements (RTAs).[5] Some of these have included liberalization in sectors relevant to transportation costs. Neufeld (2014) outlines trade facilitation measures that have been included in recent RTAs, with particular attention to commitments in areas of trade facilitation along the lines of the TFA. U.S. RTAs have included aspects of trade facilitation at least since NAFTA and encompass a broader view of the concept. The Trans-Pacific-Partnership (TPP) negotiations included increased ambition in this area, such as disciplines involving express delivery services that often have much lower transaction and transportation costs than local postal monopolies.

These types of commitments involving transportation costs are unfortunately very hard to measure since they involve changing regulations or increased access to service sectors. This makes a quantitative analysis of completed or even possible trade policy reforms relevant to transportation costs challenging. Nonetheless, we will see that a burgeoning literature has developed in recent years that helps provide empirical evidence on these issues that can illuminate the consequences of high transportation costs and possibly help inform trade policymakers.

Section III. Data and Methodologies

Methodological issues and data complications can result in important challenges facing trade analysts interested in understanding the impact of reducing transportation costs. We therefore turn briefly to a discussion of the quantitative approaches and data sources used to analyze trade and transportation frictions.

III. A. Methodologies

Formal studies of trade and transportation costs are typically of two types: gravity equation econometric studies and computable general equilibrium (CGE) simulation models. The gravity equation is by far the more frequently used framework in the relevant transportation cost literature, though the latter is the workhorse approach for economy-wide trade policy analysis used by many governments and international organizations.

The classic version of the gravity equation was *ad hoc,* albeit intuitive:

$$(1) \qquad x_{ij} = y_i^{\beta} y_j^{\delta} D_{ij}^{\alpha}$$

where x_{ij} is trade between countries *i* and *j*, D_{ij} is distance between the countries (typically distance between capitals or principle economic centers), y_i is the GDP of country *i* and y_j is the GDP of country *j*. The parameters α, β, and δ reflect the sensitivity of trade for these various factors.

Taking natural logs yields:

$$(2) \qquad \ln(x_{ij}) = \alpha \ln(D_{ij}) + \beta \ln(y_i) + \delta \ln\left(y_j\right)$$

where the parameters have a natural interpretation as various trade elasticities.

The basic intuition for this relationship is straightforward: bilateral trade in goods will tend to be higher for countries that are physically close and economically large, which is analogous to the Newtonian equation for gravitational pull. The "resistance" between countries is traditionally proxied by simple bilateral distance, but authors frequently add other variables such as former colonial ties, shared borders, and common language to augment the basic relationship about trade frictions.

Anderson and van Wincoop (2003) (hereafter AvW) and others have noted the atheoretical nature of the traditional gravity model. They develop an alternative approach based on a formal model, where each nation produces a unique differentiated good. Demand is characterized by a constant elasticity of substitution utility function in which consumers have a love of variety. If one assumes symmetric bilateral trade costs between each country pair, the resulting general equilibrium expression for trade between country *i* and *j* is:

$$(3) \qquad x_{ij} = \frac{y_i y_j}{y_w} \left[\frac{t_{ij}}{P_i P_j} \right]^{(1-\sigma)}$$

where y_w is world income, t_{ij} is the iceberg transportation cost between countries *i* and *j* and σ is the constant elasticity of substitution between goods.

The terms *Pi* and *Pj* are general prices indices for the two countries that each involve a non-linear equation that is a function of each country's income share, bilateral trade costs for each country pair, and goods prices for all countries. Anderson and van Wincoop designate these as "multilateral resistance terms" (MRT) that include the bilateral iceberg transportation costs of trading with other countries. In other words, the Anderson-van Wincoop formulation reflects not only the possibility of trade between these two countries, but also all other possible trading partners.

One obtains the estimated equation by taking natural logs of (3). In practice, the multilateral resistance terms are generally replaced by importer and exporter fixed effects, though this is not as efficient as solving the full non-linear system.

Baier and Bergstrand (2009) elaborate upon the AvW approach using a first-order log-linear Taylor expansion of the multilateral resistance terms. One can write this a reduced form linear equation where GDP-weighted (as a share of world GDP) bilateral and multilateral trade costs can be estimated using standard ordinary least squares techniques. Baier, Kerr and Yotov (2017) develop this and more recent structural approaches to the gravity model in much more detail in this handbook.

A further methodological issue remains with the use of gravity type equations for the effects of transportation cost reforms on trade. The econometric procedure typically will yield point estimates of the elasticity of trade volume with respect to a reduction in transportation costs. However, there are very difficult issues about measuring certain types of trade costs that are discussed in the next section. As a consequence, many authors do not focus on the point estimates when contemplating the effects of, say, a policy reform. Instead, we will see below that authors frequently discuss discrete movements of the country's transportation costs to some average for a relevant group of comparison countries. This approach provides more of a "ball park" figure than a precise marginal effect and also reflects the lack of exactness associated with a particular observation for transportation costs.

Gravity equation empirical models have many strengths (relative simplicity, good fit of the data, and intuitive interpretations of estimated coefficients). However, there are significant limitations. The results, for example, tell a policymaker nothing directly about downstream impacts, consumer effects, or national welfare consequences of reducing transportation costs.

In response to these limitations, trade policy analysis often turns to computable general equilibrium models that are also sometimes referred to as "applied general equilibrium" models. These models are critically important in trade policy practice, although much less common in academic studies of trade.[6] We will discuss a handful of such studies in the next section.

In many ways, CGE models are a mirror image of gravity equations. They are very complex and data-intensive, but can yield detailed estimates for the impact of particular policies on domestic welfare, labor markets, consumer spending, and resource reallocation. They do however require a social accounting matrix that reflects all transactions and transfers of resources and income for all sectors of an economy. One must also specify relevant elasticities for consumers, producers, and factor markets.

CGE models are not statistical analyses yielding a coefficient estimate and confidence interval. Instead, CGE models are multi-equation *simulations* that attempt to map an entire economy into a series of theoretically consistent relationships. Complex computational methods are used to replicate a particular year's economic data; alternative equilibria are calculated for that base year using an alternative set of policies. They are particularly helpful in understanding how resources are reallocated among sectors if an alternative policy is in place. The models' results are also used to estimate the impact on overall consumption as a result of the increased or decreased economic efficiency as a result of a policy change.

A vital input into the comparison of the trade equilibria in a CGE is a "price wedge"; i.e., how much a specific trade policy increases or decreases the price of a good or service over an alternative international source. Trade policy researchers consequently have focused on tariffs and *ad valorem* equivalents of non-tariff barriers; equilibrium values of relevant endogenous variables are compared with and without the alternative set of policies in place. This is relatively straightforward for tariffs. Restrictions on services are much harder to quantify since they involve generally involve regulations and standards. Transportation services are subject to this same complication, as are behind-the-border transaction costs associated with moving a good to a port. The uncertainties of developing price wedges for transportation restrictions probably have contributed to the rather infrequent use of CGEs for international transportation policy changes compared to other policy initiatives.

III. B. Quantifying Transportation Costs for Trade Analysis

A critical aspect of analyzing empirically the impact of transportation costs on trade is quantifying the frictions associated with transport services. A traditional approach, which is consistent with the gravity equation, is to simply use physical distance. This measure is easily obtainable, but has the clear disadvantage that it does not vary across time or industry.

In one sense, distance is immutable; New York never will be fewer than roughly 3,500 miles to London. But technological change and policy decisions can change the effective distance and thereby the monetary costs of moving goods to the final destination.

Another way to measure trade costs beyond simple distance is to use FOB (trade values exclusive of freight and insurance costs) and CIF (trade values including freight and insurance costs). In principle, the difference between these two is the cost of insurance and transportation costs, which would be a measure of the costs associated with Link 3 in Figure 1. Unfortunately, this difference is

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[6] See Kehoe et al. (2016) for a discussion of development of CGE as well as suggestions for improvements.

only rarely available in practice for the same transaction from a single data source. One might hope that the exporting countries' records of the value of exports could be matched up with the importing country's value of the same transaction. Hummels and Lugovskyy (2006), however, provide strong evidence of major measurement error using FOB and CIF as indicators of transportation costs and now they are only infrequently used in empirical studies. There are however a handful of countries that record the value of transportation and insurance in all importing transactions and so allow more appropriate use of FOB and CIF. Two important examples are the United States and New Zealand. The United States data also include information about the mode of transport (rail, air, shipping, and trucking) that provides further nuance about transportation costs.

A number of data sources developed in recent years to measure transportation costs represent significant improvements over these traditional methods. We will briefly discuss four sources: 1) *Global Competitiveness Report*; 2) *Doing Business*; 3) *Logistics Performance Index*; and 4) *Services Trade Restriction Index*. None of these four is focused exclusively on transportation costs, but they have relevant information as a subset of the data collected. The first three also do not measure trade policy's impact on transportation costs directly, but instead measure transportation cost outcomes and so are of limited use if one is interested in policy reform. These first three measures also do not have sectoral variation, but instead only measures country-level outcomes. The *Services Trade Restriction Index* is more directly relevant for policy work since it focuses on government policies that can affect foreign participation in the provision of services, including, but not limited to, relevant transportation activities.

The *Global Competitiveness Report (GCR)* has been developed by the World Economic Forum and is published on an annual basis. The relevant section of the report surveys business executives about their subjective evaluation of various modes of transportation infrastructure. The authors of this series recognize the potential problems with these subjective measures. And those examining trade policy do not have direct measures of the specific government measures that shape these private sector perceptions. Nonetheless, this series is an important early source of cross-country variation of measures of transportation outcomes.

The World Bank has compiled information about country-level worldwide private sector experiences in *Doing Business* (*DB*) since 2004 and currently reports results for 189 countries. The annuals reports have included a subsection on "Trading Across Borders" since 2006 that focuses on the time and cost of importing and exporting goods (exclusive of border taxes). The results are based on questionnaires to freight forwarders, customs brokers and traders about a standardized notional transaction for comparability. The index includes information on domestic transport costs (from a warehouse in the largest city to the most commonly used land-, air- or sea port), border costs (documents, customs, and port handling), and transportation costs to its most important market for exports. This index has the major advantage of a large annual comparison of many countries using a common methodology.

The World Bank has also created the *Logistics Performance Index (LPI)* that is intended to measure the supply chain "friendliness" of 160 countries and as of this writing is available for 2007, 2010, 2012, 2014, and 2016. This index is built up from a survey of freight forwarders and express carriers, who are questioned about issues such as customs clearance, trade infrastructure, and quality of logistics. Thus, the *LPI* is more about challenges associated with domestic trade costs than for international transactions as in *Doing Business*.

We will see that many researchers have used these three databases (*GCR, DB,* and *LPI*) in studies of trade facilitation that in turn have been utilized to analyze various scenarios. However, they do share two shortcomings: 1) there is no variation across sectors within a country; the only variation arises across countries and only somewhat over time since business realities and perceptions are slow to change; and 2) the results are based on surveys and thus inherently subjective though based on expert experience.

The World Bank also recently has developed the *Services Trade Restriction Index (STRI)* that at least partially addresses these issues. In particular, the *STRI* is a measure of 103 countries' restrictions on five service sectors, including transportation (air travel, maritime shipping, road trucking, and railway freight). Publically available information on regulations was used to construct the index for developed countries while surveys to local lawyers with extensive relevant experience were used for developing countries. This resource, which became available in 2012, will be particularly relevant for studies on transportation restrictions since it allows for both cross-country and cross-sectoral variation for different transportation modes, albeit currently for only one year.

Section IV. Empirical Studies on Transportation Costs' Effects on Trade Flows

We turn now to recent econometric work that focuses on the link between goods trade flows and frictions associated with transportation. Many of these are about analyzing either the determinants of transport costs or the impact of these costs on trade. Many of the authors have also used the results to speculate about the impact of policy reforms that might lower unnecessary frictions associated with transportation.

This section is divided into three parts. The first includes a discussion of research on the border-to-border costs of moving goods (Link 3 in Figure 1). The next section focuses on impediments at the border itself (Links 2 and 4). This literature, with a direct link to the policies addressed in the recent WTO Trade Facilitation Agreement, pays attention to port efficiency, infrastructure and customs administration. Links 4 and 5 are addressed in the third section, with studies focused on behind-the-border costs such as domestic logistics, internal transportation infrastructure, and domestic institutional quality.

While we do break these studies into these specific links, it is important to note that there can be significant overlap in the studies. For example, a study about the impact of internal transportation costs on exports often also control for border impediments. Nonetheless, this somewhat arbitrary breakdown into distinct links will help organize the discussion.

The broad outcomes of these empirical studies are certainly non-controversial: high transportation costs of various types can have economically important effects on trade outcomes. The most important contribution of this literature is that it has helped begin the task of putting specific numbers on the impact of these costs, including the relative importance of different types of transportation frictions. Some of the most prominent of the studies discussed here are summarized in Tables 1 and 2.

IV.A. Link 3: Analyzing Costs of Moving Goods Between Countries

Many modern researchers have moved beyond a simplistic view of simple distance as a sufficient statistic for analyzing the costs of moving goods from border to border. The recent relevant literature on traditional transportation costs from border to border has emphasized three broad themes: 1) the impact of innovation in transportation services; 2) determinants of maritime and air shipping costs; and 3) firms' choices among transportation modes. These studies also contain insights into the impact of government policy in the determination of the costs associated with Link 3, including for example competition policies among shipping companies and open-skies agreements for air services. We will focus on these themes specifically in the context of maritime cost and air costs, which are the two modes that dominate world trade.

Table 1: Selected Empirical Papers on Transport Costs Between Countries (Link 3)

Author	Primary focus	Primary measure of transportation/trade facilitation	Source*	Aggregation level	Year(s) analyzed
Fink, Matto, and Neagu (2002)	Effects of private uncompetitive practices and public policy on liner shipping costs	Liner transport charges as share of import value	U.S. Department of Transportation and U.S. Bureau of Census	HS6	1998
Bertho,Borchert, and Matoo (2006)	Effects of service sector restrictions on liner shipping costs	STRI	World Bank	HS2	2007
Micco and Serbrisky (2006)	Effect of U.S. Open Skies Agreements on air cargo prices	Presence of Open Skies Agreement with United States	Department of Transportation Aviation and International Affairs	4-digit SITC	1990-2003
Wilsmeier, Hoffman and Sanchez (2006)	Effects of port characteristics on maritime transport costs	Maritime shipping costs	UN Economic Commission for Latin America	3-digit SITC	2002
Piermartini and Rousova (2013)	Effect of U.S. Open Skies Agreements on passenger miles flown	Air liberalization index	World Trade Organization	Air passenger miles between countries	2005
Hummels and Schaur (2013)	Time in transit as measure of quality; modeling mode choice between air and ocean shipping	Days in transit from foreign port-of-exit to U.S. port-of-entry	U.S. Imports of Merchandise data base (U.S. Bureau of the Census)	HS6	1991-2005
Carballo, Graziano, Schaur amd Volpe-Martincus (2014)	Impact of delays at Peruvian airport or seaport on import costs	Days in transit at primary Peruvian seaport or aiport	National Tax Agency (Peru)	HS10	2011
Bernhofen, El-Sahli and Kneller (2016)	Impact of container revolution on trade volume	Adoption of containerized ports or railways	Containerization International	4-digit SITC	1960-1992

Innovation

As noted above, the physical distance between ports of entry and exit do not change. But effective distance can be changed dramatically because of technological innovation. Standardized shipping containers have sharply reduced maritime shipping costs and tied nations more closely together. In an analogous fashion, jet-powered aircraft have made certain types of international transactions much more economically viable (e.g. shipment of fresh fruits and flowers), as well as components in just-in-time production processes.

A recent study documented both the effects of reducing maritime shipping costs through containerization as well as the spread of this innovative technology. Bernhofen *et al.* (2015) analyze the impact of containerization in world trade for the 1960-1992 period.[7] They exploit two important sources of variations in their difference-in-difference analysis of bilateral trade flows at the 4-digit SITC level for 157 countries. First, they use a measure of "containerizability" based on a German engineering study, i.e., those products that are plausibly shipped using standardized containers. This approach allows for sectoral variation that, as we will see as the discussion continues, is relatively rare in the literature of transportation costs and trade. Secondly, they examine the impact of different years of country adoption of containerized shipping. They estimate that the use of containers may have increased global trade by as much as 900 percent for a 15-year period subsequent to the initial adoption of the technology in 1968. The authors also find a marked difference in the impact of containers on developed versus developing countries.

Hummels (2007) documents an analogous technological breakthrough in air transportation costs that can be traced to changing avionics, jet engines, and wing designs, among other innovations.[8] He provides evidence that as jets became much more widely used, quality- and inflation-adjusted aircraft costs fell as much 17 percent per year for the 1950-1972 period and by as much as 4 percent per year from 1972–1983. Similarly, one measure of the price of air transport services expressed in 2000 U.S. dollars fell from $3.87 per ton-kilometer in 1955 to under $0.30 from 1955–2004, with much of the drop occurring in the first 15 years as jets were introduced widely. These lowered costs clearly can have a dramatic effect on how firms use transportation services. For example, Hummels provides descriptive statistics that show a dramatic increase in the share of air transportation for U.S. trade after the introduction of jet technology. About 8 percent and 12 percent of the value of U.S. imports and exports were transported by air in 1965, respectively, compared to 31.5 percent and 52.8 percent in 2004.

Determinants of Maritime Shipping Costs and Impact on Trade Flows

A second strand of this literature looks directly at the determinants of maritime transport costs and the subsequent impact on trade flows. These studies focus on port characteristics, the degree of competition among transportation service providers, and government policies, including investment restrictions and limitations on foreign involvement in transportation.

Wilsmeier et al. (2006) find strong evidence that improved port efficiency, upgraded port infrastructure, and private sector participation in port services help reduce maritime transport costs. They focus on individual port characteristics as determinants of maritime transport costs and use a traditional gravity model to examine the impact of port characteristics for a cross-section of 16 Latin

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[7] Rua (2014) builds a Melitz-type model to examine how firms might choose to adopt container technology. She shows how heterogeneous firms might choose between two technologies: containers and traditional shipping. Her results suggest an important role for inland transportation networks as well as trade network connectivity with the United States, which was an early adopter of container technology.

[8] This paper also provides an invaluable broad survey of the role of falling transportation costs in what he calls the "second era of globalization."

American countries for 2002. The dependent variable, the log of maritime transport costs (excluding insurance), is based on transaction-level customs data, which is an important advantage of the study. The particular SITC 3-digit categories analyzed are all "containerizable." The authors use *GCR* data for 2004 as the basis of their port characteristics data.

Another strand of this literature looks at whether the degree of competition can affect the prices charged in maritime services. This reflects the plausible argument that while innovation can reduce marginal and fixed costs of transportation, the competitive market conditions can be critical in determining final costs, with potential subsequent impact on trade flows.

Fink et al. (2002) analyze the effects of the degree of firm competition among ocean shipping firms, including both private price-fixing arrangements as well as public policies. In particular, they examine the impact of uncompetitive practices on prices charged for scheduled maritime cargo shipping routes (so-called liner shipping) using 6-digit HS (Harmonized System) U.S. import data for 1998 for 59 countries. The authors find little evidence that cargo reservation requirements (whereby governments require a certain percentage of the freight be carried by domestic shipping firms) play a statistically significant role in the liner shipping costs. There is stronger evidence that private collusive behavior and cargo-handling restrictions contribute to higher shipping costs. The first result may reflect the fruits of past liberalization of reservation requirements in recent decades. The latter two results suggest that there could be further benefits from liberalization in these areas, especially with regard to private practices. The authors estimate that eliminating price collusion and liberalizing cargo-handling services could reduce liner costs by 44 percent and 35 percent, respectively.

Naturally, supply conditions are not the only determinants of market outcomes. For example, the structure of demand can also play an important role in a high fixed cost industry such as ocean-going shipping. For example, Hummels et al. (2009) focus on how different consumer preferences can interact with oligopolists to affect maritime shipping costs. They develop a theoretical model that relates import demand elasticity to the market outcomes of Cournot oligopolists in shipping. They then use HS-6 level data from U.S. imports for 1991-2004 to evaluate their predictions on the determinants of freight charges. The authors find that products with lower import demand elasticities are associated with higher freight costs. They also examine data for Latin American countries and find similar results. Their results suggest, for example, that doubling the number of shippers to Latin American countries could reduce maritime costs by as much as 16 percent.

However, private sector demand and supply conditions are not the only determinants of shipping costs. Government policies that limit international competition can also play a role. There is certainly a long history of nations limiting foreign participation in shipping, sometimes out of national security concerns and sometimes out of more narrow protectionist incentives.

For example, the U.S. Merchant Marine Act of 1920 (better known as the "Jones Act"), requires that the transport of cargo between U.S. ports must be provided by U.S. crews operated on U.S. built vessels under U.S. registration. Francois et al. (1996) use a CGE model analysis to examine a scenario of complete liberalization of restrictions on domestic water transport by a foreign operator (i.e., cabotage) and find net benefits of US$ 2 billion to US$ 3.4 billion annually. Their scenarios are based on three possible price wedges: 50, 100, and 150 percent, that are based on a range of estimates of U.S. versus foreign prices for shipping. The U.S. International Trade Commission (2002) also uses a CGE and finds a more modest welfare change for a complete liberalization of U.S. cabotage (US$ 656 million), which reflects a lower estimate of the price wedge (40 percent). A noteworthy aspect of both studies is that the authors note that there is considerable uncertainty about the exact amount of the price distortions.

Bertho, et al. (2016) examine the impact of another government intervention that can affect transport costs. In particular, they analyze foreign investment restrictions in relevant transport service sectors on liner shipping costs and use the World Bank's recently available *STRI* database (discussed above) to do so. They exploit HS-2 import data from the United States, New Zealand, Brazil, and

Chile for 65 exporting countries to calculate maritime trade costs. They proceed in two steps. The first is an estimate of the determinants of maritime shipping costs where countries are sorted into four quartiles based on *STRI* transportation sector restrictions. They find consistent evidence that increasingly restrictive transportation sector investment leads to significantly higher maritime costs: 26 percent, 35 percent, and 68 percent higher liner costs relative to the first quartile for the second, third, and fourth quartile, respectively. In the second stage, the authors use an AvW-style gravity model and a Pseudo Poisson Maximum Likelihood (PPML) procedure to examine the effects of these higher costs on trade volumes. The elasticity of trade volumes with respect to maritime transport costs is higher than those for distance, common language, tariffs, and membership in a regional trade agreement. The authors interpret these results as strong evidence that investment restrictions in the shipping sector create important distortions in trade and provide an important area for negotiations in trade policy agreements.

Determinants of Air Transportation Costs and Trade Flows

We noted above that technological innovation has increased dramatically the role of planes in the movement of goods across borders. Consequently, a large number of studies have been undertaken in recent years that focus on various aspects of air transport services, both for cargo and passenger services. Much of this work is reviewed in Yahua Zhang et al. (2017) in this volume but a few particular papers are worth mentioning here.

One aspect is the role of specific government policies that can affect the competition between domestic and foreign air transport services. For example, governments have negotiated various types of "open skies agreements" (OSA) on an *ad hoc* basis and outside of the GATT system. These agreements liberalize the access of foreign carriers inside domestic markets both for freight and passenger services. Researchers have found consistent evidence that such liberalization can improve various measures of market performance, including air freight costs, air passenger fares, and volume of passenger flights.

Micco and Serebrisky (2006) focus on the impact of OSAs on air transportation costs and find important economically important effects on prices. They note that U.S. OSAs contain common features, including no restrictions on the number or capacity of airlines serving international routes into the U.S. and market-determined pricing. They examine the impact of OSAs on U.S. air transport freight costs for 1990 to 2003 using detailed 4-digit SITC U.S. import data at the customs district level. Their panel data specification suggests only a small impact of OSAs on air cargo fees in the short run, but an increasing impact for agreements in place more than five years. One of their specifications suggests that liberalization through OSAs have reduced air transport costs by as much as 9 percent and increased the share of imports coming by air by 7 percent.

Piermartini and Rousova (2013) broaden this analysis to include the impact on the volume of passenger flows among 184 countries that had air services agreements in place in 2005. They also use a gravity-type approach to examine various types of air service liberalization. The authors find significant impacts of these agreements and estimate that a country that reduced its air traffic restrictions from the 25th to 75th percentile could increase passenger volume by as much as 29 percent.

Winston and Yan (2015) focus more specifically on the impact of U.S. liberalization in air services on international passenger fares. Their analysis of 66 international travel routes either originating in or terminating in the U.S. is based on a full market equilibrium modeling structure. They focus on two different types of policy outcomes: 1) "traditional" agreements that retain at least some regulatory restrictions; and 2) "open sky agreements" that involve much deeper liberalization. They estimate at least US$ 4 billion of contemporaneous annual benefits to travelers a result of both types of liberalization, with an equivalent welfare improvement possible if the agreements were extended to other countries.

Winston and Yan mention another target of further liberalization: important air passenger restrictions inside most countries, which is analogous to the Jones Act restrictions discussed above for shipping. For example, the United States does allow foreign airlines to continue international flights within the U.S. (e.g. a Lufthansa flight from London to San Francisco can stop in New York), but the airline may not pick up new passengers in New York. Foreign airlines also may not operate solely between U.S. airports. This remains an important possible subject of future research.

Choosing Among Transportation Modes

The studies above on maritime and air costs examine these transportation options in isolation. Other studies look at the firm choices between modes; this provides at least some context, for example, to the decisions of governments to choose possible transportation modes for further liberalization.[9]

Hummels and Schaur (2013) develop a formal model of an exporter's choice between moving goods by airplanes or by ships. They use U.S. merchandise import data at the HS-6 digit level for 1991-2005 to evaluate the model. The authors estimate that each day in transit is the equivalent of a tariff of as much as 2.1 percent. They also split the sample into end-use categories for products. The estimation results are consistent with a world where automotive products, capital goods, and perishable items are much more sensitive to time delays and therefore more likely to be moved using air freight. The authors argue that these results can help policy makers choose where to put scarce resources for trade facilitation since the work helps put a value on the days potentially gained from infrastructure investment and policy reform for different transportation modes.[10]

The choice between airplanes and ships in fact takes place at the firm level. Individual companies may find that their commercial interests are more sensitive to time delays at the border and time in transit to final customers. Carballo et al. (2014) are able to examine this choice for very disaggregated decisions in Peru.[11] Their rich data set allows them to document port delays for air and sea options using 2011 Peruvian HS 10-digit transaction level customs data that is linked to individual firm level data from the Peruvian tax ministry. Their data allows the authors to control for firm-level heterogeneity, which is a rarity in trade and transportation studies. They estimate that one extra day at the main Peruvian airport could raise costs by 1.6 percent. They also report differences between small and large firms for the seaport option: a one-day delay raises costs by 0.7 percent for small firms and 0.9 percent for large firms. These estimates are of similar magnitude to those in Hummels and Schaur. This study highlights one important aspect largely absent from the literature: transportation costs can have heterogeneous effects of firms based on their individual characteristics, which could imply differential impact of policies undertaken by governments.

IV.B. Links 2 and 4: Border Administration, Customs Costs, and Port Efficiency

Analysts have focused increasingly on the fact that trade flows can be affected not only by costs associated with Link 3 but also by delays at the border. These costs can include those associated with

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[9]   Cristea et al. (2013) develop an approach that allows for comparing the impact of carbon emissions using aviation, maritime, rail, and truck modes for moving freight across borders. The authors then simulate the impact of trade liberalization on the growth of emissions using a CGE framework and find that broad trade liberalization that could result in greater use of much more carbon-intensive air cargo and ocean shipping modes and away from less carbon-intensive railway and trucking options. While international policy has not yet focused on the effects of trade liberalization on global carbon emissions through transportation choices, this could be an important area for policy analysis in the decades ahead.

[10]   Evans and Harrigan (2005) focus on the different aspect of transportation delays: the growing importance of timely delivery of products in specific retail sectors, with a particular focus on apparel imports. They find that sourcing clothing from a nearby country can have economically important effects on the pattern of trade.

[11]   This team of authors has produced a number of important recent studies including Carballo et al. (2016a), (2016b) and (2016c). A summary of related literature can be found in this handbook at Carballo et al. (2017).

loading goods onto ships or airplanes, clearing customs, obtaining proper documentation and satisfying other domestic regulations. A growing literature has developed around this theme, with specific focus on three aspects that will be discussed below: 1) port efficiency; 2) customs rules and administration; and 3) port infrastructure.[12]

These issues have taken on particular importance as policymakers and trade negotiations have focused increasingly on these border frictions. As noted above, WTO members concluded the Trade Facilitation Agreement in December 2015. The TFA touches only lightly upon behind-the-border facilitation and focuses instead on aspects of border costs such as customs administration and sharing of regulatory procedures with potential foreign partners. In other words, the agreement is very much in the spirit of existing GATT provisions in Articles V, VII, VIII, and X discussed above.

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[12] See Blonigen and Wilson (2017) for a broader discussion about port efficiency.

Table 2: Domestic Transportation Costs of Exporting Goods (Links 1, 2, 4, and 5)

Author	Primary focus	Primary measure of transportation/trade facilitation	Source*	Aggregation level	Year(s) analyzed
Limao and Venables (2001)	Effects of domestic infrastructure and geography on maritime transport costs and bilateral trade flows	Maritime shipping costs from Baltimore	Questionnaires to private freight handlers	Bilateral aggregate exports	1990
Clark, Dollar, and Micco (2004)	Determinants of shipping costs to US, with focus on port efficiency	Port handling costs	Global Competitiveness Report	HS6	1998
Blonigen and Wilson (2008)	Estimating individual port efficiency effects and their impact on trade flows	Importing and exporting port fixed effects; weight and value of imports; container useage	Army Corp of Engineers	HS6	1991-2003
Martinez-Zarzoso and Marqez-Ramos (2008)	Effect of export fees and export delays on sectoral trade	Export fees and days required for export	Doing Business	SITC 4-digit	2000
Wilson, Mann, and Otsuki (2005)	Benefits of trade facilitation reform on exports	Port efficiency, customs environment, and service sector infrastructure; regulatory environment	Global Competitiveness Report; Kauffman et al. (2002)	Bilateral aggregate trade	2000-2001
Iwanov and Kirkpatrick (2007)	Effects of trade facilitation quality and regulatory environment on trade volumes	Hidden export barriers, irregular export and import payments; number of documents for export/imports, days required for export/import, costs for export/import goods; regulatory quality	Global Competitiveness Report; Doing Business; Kauffmann et al. (2005)	SITC 5-8 and SITC 68	2000-2004
Djankov, Freund, and Pham (2010)	Effects of transit delays on trade volumes of 146 countries	Days required for export	Doing Business	Bilateral aggregate trade	2001-2003
Freund and Rocha (2011)	Effect of transit times, documention requirements and border preocedures s on African exports	Days required for export	Doing Business	Bilateral aggregate trade	2007
Hoekman and Nicita (2011)	Compare impact of logistics and trade cost reform with tariff and NTB liberalization	Costs for exporting or importing goods; logistics quality	Doing Business; LPI	Bilateral aggregate trade	2006
Portugal-Perz and Wilson (2012)	Relative effects of improvements in "hard" and "soft" infrastucture effect on export performance of developing countries	Information and communications technology; physical infrastructure; business environment; and border and transport efficiency	Global Competitiveness Report; Doing Business; Transparency International	Bilateral aggregate trade	2004-2007

Persson (2013)	Impact of export delays on intensive and extensive margins of developing country exports to E.U.	Days required for export	Doing Business	HS8	2005
Saslavsky and Shepherd (2014)	Compare the impact of logistics quality on trade in final goods and components trade	Logistics quality	LPI	HS2	2007
Beverelli, Neumueller and The (2015)	Impact of trade facilitation measures on extensive margins (number of products or number of destinations)	Unweighted average of 16 trade facilitation measures	OECD Trade Facilitation Index	HS6	2009

* See original papers for more details on data sources.

Hoekman (2014) provides a very useful summary of the promise and shortcomings of this approach. For example, the agreement allows for slow implantation of the negotiated disciplines for developing countries and often commits countries only to "best endeavors" towards good practice rather than enforceable commitments. As Hoekman points out, the relevant literature on the impact of trade facilitation, some of which is discussed below, provides compelling evidence about a nation's own interest to invest in lowering the costs of moving goods into and out of a country, regardless of whether these costs occur at the border or are incurred in the movement of goods from factories on domestic rail and roads towards a port. However, the TFA's final outcome also reflect a major hole in the existing literature, which generally does not look at the cost of implementing transportation cost reform. This of course can be of paramount importance to a developing country with limited financial resources. These potentially daunting costs may have contributed to the low level of ambition in the TFA for developing countries themselves.

Beverelli et al. (2015) consider this narrower definition of trade facilitation consistent with the TFA that focuses more narrowly on border administration improvements (and not on behind-the-border problems), with particular attention to sub-Saharan Africa and Latin America. Unlike other studies on trade facilitation discussed below, they use the OECD Trade Facilitation Index (TFI) that the authors argue is more easily mapped into the specific agreements of the TFA. They use a Baier-Bergstrand gravity approach (utilizing OLS, PPML, and negative binomial regressions) with two different dependent variables: 1) the number of products exported to a trading partner; and 2) the number of countries that import a particular product from a specific exporter. Their data is highly disaggregated (HS-6) for 2009; new products/markets are based on whether the goods are exported in 2002-2007 versus 2008-2010. They find that these particular types of trade reforms in the TFA increase the extensive margins. They also report a simulation scenario where sub-Saharan African countries with below average TFI scores could increase the number of goods exported by 18 percent or the number of serviced export markets by 30 percent if they improved their TFI to a regional median.

Clark et al. (2004) also focus narrowly on the impact of border costs on maritime shipping costs using HS-6 U.S. import data from developed and developing countries for 1996, 1998, and 2000. They find that that container handling costs are strongly negatively correlated with poor port efficiency as measured by the 1999 *GCR* survey results about port infrastructure, mandatory cargo handling arrangements and measures of organized crime at the ports. They then use a traditional gravity equation setup to measure the effect of their constructed trade cost index on trade flows. One of their estimates suggests that improving port efficiency from 25th to 75th percentile is the equivalent of reducing distance to final market by 5000 miles or an increase in trade by 25 percent.

The Clark et al. approach exploits cross-product variation to examine port efficiency but one might easily imagine that there could be systematic differences across individual ports. Some may have more modern infrastructure, better management, and other unobserved variation. Blonigen and Wilson (2008) use a novel approach to indirectly measure these types of costs at the individual port level. Rather than concentrate on country-level port costs, they focus instead on particular ports' efficiency by using detailed HS6 import data for individual U.S. customs districts for 1991-2003 involving 375 U.S. ports of entry and 1789 connecting ports.[13] This approach, which is not based on survey data such as the *Global Competitiveness Report* used by Clark et al., exploits important variation across products and ports to examine trade costs. The authors use individual port fixed effects to uncover metrics of port efficiency from the data. As in many other studies, the authors first fit import charges to explanatory variables (including the individual port fixed effects) and then include a weighted average of individual port efficiencies in a traditional gravity equation model to explain bilateral trade flows. They estimate that an improvement in port efficiency from the 25th percentile to the 75th percentile leads to a 5 increase of bilateral trade, or only one fourth of the similar counterfactual discussed in

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[13] Note that the sample used in the econometrics is truncated because of computational constraints.

Clark et al. based on the *GCR* survey results. This comparison reflects both the possible downsides of using survey data and the important advantages of using more disaggregated information to calculate trade costs.

Djankov, Freund, and Pham (2010) use data from the *Doing Business* survey to examine the impact of delays on country-level exports for 146 countries for a single year (2005). The authors use a detailed questionnaire to freight forwarding companies to examine the impact of delays on the volume of trade and thus follow in the spirit of Limao and Venables (2001) that is discussed below. Rather than looking at the natural log of trade for a country pair as in most gravity equation estimation, they estimate the natural log of exports for two "similar" exporters based on location and factor endowments, which control for "remoteness" and levels of economic development. Their benchmark model suggests that relative exports could rise by 4 percent if relative delays were to fall by 10 percent. They also recognize that trade costs could fall if trade volumes increase. In one specification, they deal with this potential endogeneity by limiting the sample to land-locked countries and use the transit times in neighboring countries as an instrument; the results are consistent with their baseline estimation approach.

IV.C. Links 1 and 5: Including Behind-the-Border Costs

Researchers generally have taken a broad view of trade facilitation that includes internal impediments as well as pure border effects in their analysis. This research documents the importance of behind-the-border costs such as domestic infrastructure, logistics, and institutional quality in influencing trade flows. A notable feature of some of these studies is that many authors have tried to assess the relative importance of these frictions, at least in part because this may help governments understand where to focus scare resources used for reform.

Domestic Infrastructure and Logistics

Limao and Venables (2001) examine how domestic infrastructure and geographical location can affect bilateral trade flows in a cross section of 1990 data for 103 countries. The authors first examine determinants of trade costs, measured either by private firm quotes for moving a standard container from Baltimore to destinations around the world and, in other specifications, IMF country level data for CIF/FOB ratios. They then estimate the effect of these bilateral aggregate trade costs on goods flows using Tobit (because of the many zeroes for bilateral trade relationships). Explanatory variables for trade costs include standard regressors such as distance, as well as indicators for island or land-locked countries. They also include domestic frictions through a measure of infrastructure based on domestic road and rail networks and telephone lines per person obtained from Canning (1998). They find significant and consistent evidence that poor domestic infrastructure can lower trade volumes. Taken together, the authors estimate that a deterioration of infrastructure from the 50th to 75th percentile in their sample could increase the cost of shipping a container by the equivalent of an additional 3466 kilometers. They argue that these results reflect the importance of improving domestic infrastructure to increase exports.

This study by Limao and Venable is notable for two reasons. The first is that it is an early attempt to standardize the measure of transport costs by obtaining quotes of transporting a container and thus anticipates the approach taken in *Doing Business* (although their sample is restricted to transactions from one U.S. port). This approach of course is only possible because of the widespread adoption of the routinized shipping approach of containerization. The other is that the measure of infrastructure is about internal *domestic* costs and not just about border and international transportation effects.

Understanding broader measures of trade facilitation are particularly important for developing countries, and World Bank economists have led the way in examining the effects of reducing related transactions costs. Freund and Rocha (2011) examine how different types of internal and border costs impede African exports. They focus on transit times for 146 countries using *Doing Business* survey

results. A gravity equation for 2007 bilateral exports is used that includes a measure of remoteness in the spirit of Anderson and van Wincoop, as well as three distinctive measures of country-specific average transit times: time necessary to complete documents required for exports; domestic transit delays; and days spent at customs and ports. They find especially important negative effects of inland transit delays across a number of specifications involving African exports: they estimate that an increase of one day in transit times on average can reduce exports by 7 percent.

Hoekman and Nicita (2011) also find that behind-the-border impediments to trade are especially problematic in developing countries compared to other trade frictions. They compare the impact of logistics performance and trade facilitation improvements with that of both tariff and non-tariff barrier liberalization in the export markets for these developing countries. Their results suggest that internal logistics have a bigger effect on exports and imports than tariffs or border impediments. The authors use a PPML approach to estimate a gravity model (including a Baier-Bergstrand control for multilateral resistance in some specifications) for a 2005 cross section of 108 countries. Logistics quality in the developing country exporters is measured by the *LPI* while the domestic transactions costs of exporting goods is proxied by the *DB* indicators. Counterfactuals suggest that low-income country exports could increase by almost 11 percent if they faced the same average tariffs that confront middle-income countries; a similar counterfactual for *Doing Business* and *LPI* would result in increased exports of 2 percent and 15 percent, respectively. An unusual feature of this study is to simulate an analogous experiment on the impact on increased imports (i.e. Link 5); the results are an increase of 7 percent, 5 percent, and 9 percent for tariffs, *Doing Business*, and *LPI*, respectively.

Differential Impact on Different Sectors

The studies discussed above show a consistent pattern of behind-the-border frictions affecting trade at the country level. However, an emerging and important theme of many strands of the literature is that different sectors may be affected by transportation and logistics costs in different ways. We already mentioned the transaction level work on Peru by Carballo et al. (2014) who focused on the border delays for air vs. shipping modes. Similarly, Hummels and Schaur (2013), find important variation in the costs of times delays across sectors.

Other literature has focused on homogeneous versus differentiated goods and find systematically different trade facilitation impacts. Martinez-Zarzoso and Marquez-Ramos (2008) for example try to disentangle the effects of trade frictions (as measured by *DB* indicators) on these different sector types. They estimate a gravity equation for a sample on a cross-section (for year 2000) of 13 exporters and 167 importers for trade for homogeneous and referenced-priced goods as in Rauch (1999).[14] The parameter estimates for their trade facilitation measures are broadly consistent with the expectations that increased transactions costs will decrease trade flows for these differentiated goods. In sharp contrast, they do not find a statistically significant effect for the homogeneous goods subsample.

Persson (2013) also emphasizes the disparate effect that trade facilitation performance has on distinct types of goods. She argues that developing countries would benefit through export diversification if lower transport costs would encourage the exports of differentiated goods rather than commodities. Her empirical study of EU25 HS-8 imports from 130 developing countries is designed to empirically assess whether there is a systematic difference between types. The dependent variable in this study is the number of distinct differentiated and homogeneous goods (also based on Rauch (1999)). Independent variables in the base specification include standard gravity equation regressors, as well as the number of days needed to export from the *Doing Business* database. The Poisson estimation approach (with Baier-Bergstrand multilateral resistance terms) yields consistent results that the number of differentiated goods exported could be twice as sensitive to time delays as

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[14] The authors also estimate the same model separately for the three industry categories that were used in the 2006 *Doing Business* report (SITC 07--coffee, tea, and cocoa; SITC 65--yarn and fabrics; and SITC 84--articles of apparel and clothing). The list of sectors was expanded in later versions of *Doing Business*.

homogeneous goods. One specification suggests that a 1 percent reduction in the number of days for export could increase trade to the EU by 0.6 and 0.3 percent for differentiated and homogeneous goods, respectively. In other words, she finds that, like Martinez-Zarzoso and Marquez-Ramos, differentiated goods are more likely to be affected negatively by transportation frictions than commodity-type products.

Saslavsky and Shepherd (2014) use a different cut of the data to examine differential impact of transportation frictions and also find important variation of effects across sectors. In particular, they segment a cross section of trade flows for 228 countries for 2007 into two types (based on Ando and Kimura (2005): 1) machinery parts and components; and 2) final consumption goods. They expect that logistics is particularly important in a world with integrated and dispersed production networks measure: flows of components across borders should be negatively correlated with logistics costs as measured by the World Bank's *LPI*. Their results suggest that parts/components are much more sensitive to logistics costs than are final goods, especially in the Asia Pacific region where fragmented production activities often are located.

Institutional and Regulatory Quality

Other studies about domestic impediments have tried to disentangle the comparative effects between distinct types of behind-the-border transaction costs on trade outcomes: 1) physical transport costs that reflect real resource requirements, such as domestic transportation infrastructure and logistics quality; and 2) costs associated with institutional quality and elective administrative procedures. These studies generally look at determinants of what might deter exports; there is far less focus on how these two types of costs might limit welfare-improving imports. The econometric results about the relative importance of these physical costs versus institutional costs uniformly show that both can affect trade flow. Unfortunately, the studies do not show a consistent pattern about the *relative* importance of the two types of frictions.

Wilson, Mann, and Otsuki (2005) represent an early attempt to distinguish between these two types of domestic trade costs and find that infrastructure improvements may have a much bigger effect on trade than institutional reform. In particular, they examine the impact of trade facilitation on exports using four broad measures: 1) port efficiency for seaports and air transport; 2) customs environment; 3) regulatory quality; and 4) service sector infrastructure, as measured by the speed and cost of the Internet and e-commerce use. All of these variables are sourced from the 2001 *GCR* except for regulatory quality, which is taken from Kauffman et al. (2002). They use these regressors in a gravity equation structure with country fixed effects to evaluate the impact of transportation infrastructure (among other variables) on exports for 75 countries for 2000 and 2001. Their results suggest that improvement in any of their four measures of their measures for trade facilitation would increase exports. They conduct a simulation to evaluate how trade would be affected by moving countries that are below average in a particular trade facilitation measure to the global average. If all countries experienced this improvement in service sector infrastructure, exports could increase as much 4.0 percent. Similar improvements in port efficiency would increase exports by 2.8 percent. Improving the regulatory environment 2.1 percent, respectively. In short, they find that institutional reform has the smallest impact on exports among these three variables.

Iwanow and Kirkpatrick (2007) in contrast estimate that domestic institutional reform could increase exports by almost twice that of an improvement in trade facilitation. Their basic econometric approach utilizes the AvW gravity setup with traditional independent variables to explain manufacturing sector exports for 78 countries for the 2000-2004 period. They find that a 10 percent improvement in their trade facilitation measures (based on the *Global Competiveness Report* and *Doing Business* indicators) would increase exports by about 5 percent. A comparable level of improvement in the domestic regulatory environment (as measured by the World Bank's "rule of law" governance quality indicators (Kauffmann et al. (2005)) could increase exports by as much as 11 percent. A domestic infrastructure reform could result in about a 9 percent rise in exports.

Portugal-Perez and Wilson (2012) also consider the relative importance of institutional quality and various measures of costs of moving goods internationally. They examine two indicators of "hard" infrastructure (proxied by transportation system infrastructure and information/communication networks) and two measures of "soft" infrastructure that reflect policy and administrative burdens (business/regulatory environment and border procedures). They use a Heckman sample selection procedure to estimate a Baier-Bergstrand style gravity framework for country-level trade data for 100 nations for 2000-2007. They find evidence that physical infrastructure plays a more important role than "soft" infrastructure. They report outcomes of a simulation exercise where they compute how much tariffs on countries' exports would need to fall to generate the equivalent trade effect from an infrastructure improvement. Their estimates suggest, for example, that improving Chad's physical infrastructure "halfway" to that of the regional leader South Africa would be the same as a tariff reduction of 24 percent on Chad's exports. In contrast, an improvement in Chad's border procedures efficiency to half of South Africa would be the same an 8 percent tariff reduction.

V. Policy Implications of Existing Research

Much of the recent literature above was undertaken, at least in part, to inform policy choices by governments. We have seen, for examples, estimates about the market impact of increased competition in maritime services and the impact of improved domestic logistics on exports. The literature also contains work that attempts to weigh the relative importance of domestic infrastructure deficiencies, border procedures, and domestic regulatory regimes. Moreover, many of these papers were motivated specifically about the impact of trade facilitation liberalization efforts recently undertaken at the multilateral level.

However, it is important to reemphasize that much of the existing research is typically about outcomes and not specific policy changes. *Doing Business* can tell one how many days it takes to export a good from Burundi, but it is silent on what specific policies might lead to that result. This is particularly important when applying the lessons learned from this research to practical policy outcomes. This limitation is particularly noticeable when comparing the various "counterfactuals" that arise out of the empirical studies. The general approach is to arbitrarily move a country's trade facilitation measure to some other country group's average. There is little discussion about what specific policies might actually accomplish these changes. This of course is not a trivial question for any government trying to use the lessons learned from the existing research.

The empirical literature reviewed here also is broadly focused on what explain or affect export performance. There is relatively little focus on how improving trade facilitation measures might improve imports (though Hoekman and Nicita (2011) is a notable exception). This is a significant shortcoming given the broad literature on the benefits of importing goods (e.g. capital goods) into developing countries.

A related issue is that there are few attempts to examine the costs of implementing reforms and the broad net welfare effects of trade facilitation efforts. Governments, especially those in developing countries with limited resources, may be loath to undertake significant reforms that improve transportation infrastructure even if there might be important trade effects. At the very least, they need a sense of both the costs and the benefits of such activities before committing the necessary resources.

In large part, these shortcomings reflect the use of a gravity equation approach in this literature that does not lend itself to analysis of welfare consequences. An obvious alternative approach is to expand the use of CGE models discussed in Section III above that allow for a complete economy-wide analysis of the impact of reduced transportation frictions. However, as noted earlier, many of the estimates about these frictions found in such sources as *Doing Business* or the *STRI* do not lend themselves easily to the type of quantification so important to these simulations. Nonetheless, they retain the critical advantage that they allow for welfare simulations that are driven in part by the costs,

as well as the benefits, of decreasing transportation frictions affecting both imports and exports of goods.

VI. Conclusion

The study of the impact of transportation costs on trade has taken a greater importance in recent years. Analysts have become much more aware of how trade flows have been affected by transportation innovation, especially standardized shipping containers and jet-powered aircraft. The former has allowed for dramatically lowered costs of bulk shipping while the latter has contributed greatly to quick delivery of time sensitive goods. In addition, researchers have focused increasingly on impediments to trade at or behind national borders. This emphasis reflects the growing concerns about trade facilitation, especially in international trade negotiations. Researchers at the World Bank and the other development institutions such as the Inter-American Development Bank have played an especially important role in furthering our understanding of the impact of transportation and trade facilitation costs on exports, with a particular focus on developing country experience.

The broad message of that research, most of which is based on modern versions of the gravity equation, is consistent and not unexpected: reforms of border administration, customs procedures, port infrastructure and domestic economic conditions can play an important role in further integrating developing countries into the global economy. These results are reflected in a variety of time periods, levels of aggregation, and country samples.

There are important remaining issues surrounding the existing literature however.

First and foremost, the databases used to measure trade costs at or behind the border remain problematic. Survey data remain at the heart of the most widely used measures, including the World Economic Forum's *Global Competitiveness Report* and the World Bank's *Doing Business* and *Logistics Performance Index* reports. Such questionnaire-based indices are inherently subjective. That said, these sources are clearly superior to earlier approaches that looked at the difference between exporting country FOB data and importing country CIF data as a measure of transportation and insurance costs (a methodology that has been shown to involve serious measurement error) or even simple physical distance between capitals. These new sources also have a major advantage in that they are compiled using a standard methodology for each separate measure.

One important challenge is that these measures typically do not vary across exporting sectors. There is certainly evidence discussed above that the impact of even these country-level measures varies across sectors. One suspects that more sector-specific measurement would yield even more persuasive results. The World Bank's *Service Trade Restriction Index* is a step in the right direction since it reports impediments that vary across sectors.

Empirical studies in the recent broader trade economics literature generally are more and more focused on firm and transaction level data to capture the idiosyncratic effects of trade costs on individual firms. One might expect that firm-level effects would also be important from a transportation cost perspective. Some work has started to emerge that examines transaction level variation in transportation costs with various studies by the team of Carballo, Graziano, Schaur and Volpe Martincus as notable examples. Studies at this level of detail are of course limited by access to more detailed and richer data sets; such research is likely to emerge in the coming years and would be very welcome.

The existing research also typically focuses on the impact of a particular country's transactions costs on its own exports. As Hoekman (2014) points out, there is relatively little research on the impact of international improvements in trade facilitation as opposed to an individual country's own domestic improvements. This is particularly important given the public goods aspect of efforts such as

regional upgrading of transportation infrastructure or coordination of customs or border processing procedures.

Falling traditional trade barriers have increased the relative importance of transportations costs in the movement of goods across borders. Some of these costs are related to the physical distance between markets. But some of them are the result of decisions that governments make about regulations and red tape at the border as well as investments in seaports, airports, and domestic transportation infrastructure. Commercial relations and trade policy will almost certainly be focused more intensively on these issues in the coming decades. Hopefully trade economists' research will provide hard evidence about how governments can help lower these transactions costs.

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