

## **A Virtuous Circle?**

### **Regional Tariff Liberalization and Scale Economies in Transport**

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## 1. Introduction

It is common when analyzing the effects of trade liberalization to take other trade frictions as given. This is consistent with a modeling strategy that focuses on how and where goods are produced, but ignores the manner in which they are shipped from location to location. But of course, arbitrage does not happen magically. It requires inputs in the form of transportation, warehousing, and distribution in foreign markets.

These inputs are not limited to transportation services in the traditional sense. They may also include information services: learning about foreign markets, as well as coordination and communication between home and abroad. Jones and Kierzkowski (1990) note that “service links” of this sort are especially important when the trade in question involves fragmenting production processes across countries.

These service links are subject to potentially large increasing returns to scale. For example, a multinational firm wishing to sell into a foreign market may pay large fixed costs in order to gather market information, tailor product specifications to local standards, or establish centers for distribution and after sales service. In each case, the average cost of the service link is decreasing in the foreign sales volume. It follows that tariff liberalization, by expanding foreign sales volume, may have a virtuous side effect. The cost of service links drop, reinforcing the tariff liberalization.

In this paper we focus specifically on the transportation link. The circumstantial evidence for investigating scale economies in shipping can be seen by examining freight costs for large versus small exporters. Consider Japan and the Ivory Coast, equi-distant from the US West and East Coasts, respectively. US imports from the Ivory Coast pay

shipping costs twice as high as those from Japan, even after adjusting for differences in the commodity composition of trade.<sup>1</sup>

What is the source of scale economies in shipping? One possible source lies in the domestic trade infrastructure built up by each country. Ports (and the internal road or rail system necessary to reach them) tend to be large lumpy investments. If the fixed costs are large enough, increased trade scale will benefit the investing country directly, and perhaps some of its trade partners, through lowered shipping costs.

Scale economies may also operate at the level of the country pair and the trade route. The capacity of a modern ocean-going liner vessel is large relative to the quantities shipped by most exporters. As a consequence, goods are almost never shipped point to point directly between the exporter and importer. Instead, a liner vessel may stop in a dozen ports in many different countries. Table 1 displays two typical port-of-call itineraries for liner vessels between North and South America.<sup>2</sup> Each route involves five or more countries, and multiple stops within each. Considering all exporting routes to the US, the median number of countries visited by each ocean liner on a single route is ten.

As trade quantities increase it is possible to more effectively realize gains from four sources. First, a densely traded route allows for effective use of hub and spoke shipping economies – small container vessels move quantities into a hub where containers are aggregated into much larger and faster containerships for longer hauls.

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<sup>1</sup> This difference in freight costs is 6.5 percent ad-valorem. This number is robust to two methods of calculation. The first method directly compares goods imported from both countries (a fairly small set). The second method subtracts commodity-specific means, then constructs an aggregate rate as the simple mean over all shipments for each exporter.

<sup>2</sup> Vessel itineraries taken from [www.shipguide.com](http://www.shipguide.com).

Examples include the European hub of Rotterdam, as well as Asian hubs in Singapore and Hong Kong.<sup>3</sup>

Second, the movement of some goods requires specialized vessels. Examples include ships specialized to move bulk commodities, petroleum products, refrigerated produce, and automobiles. Increased quantities allow introduction of these specialized ships along a route. Similarly, larger ships will be introduced on heavily traded routes, and these ships enjoy substantial cost savings relative to older smaller models still in use. (One source of scale advantage is in crew costs, which are roughly independent of ship size.)

A historical example of these effects in combination can be seen in the introduction of containerized shipping. Containerized shipping is thought by many specialists to be one of the most important transportation revolutions in the 20<sup>th</sup> century. The use of standardized containers provides cost savings by allowing goods to be packed once and moved over long distances via a variety of transport modes (truck, rail, ocean liner, rail, then truck again) without being unpacked and repacked.

Despite these advantages, containerized shipping did not diffuse immediately throughout the world. Instead, it was first introduced in the US in the 1960s, then on US-Europe and US-Japan routes in the late 60s and 70s, then to developing countries from the late 70s onward. In Figure 1, we display the share of liner tonnage that is containerized for US imports in 1979, 1983, 1991, and 1997. Each data point represents a major trade route, and we graph the container share against the sum of country GDPs on that route. Latin American routes are denoted: square for Caribbean, circle for the

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<sup>3</sup> Given the fairly linear geography of coastlines in North and South America it is not entirely clear whether it is feasible for a similar hub system to arise.

east coast of South America, triangle for the west coast of South America. This graph shows a few interesting broad patterns. The degree of containerization varies markedly across regions, is positively correlated with route GDP, and most of the growth in this period occurs on smaller GDP routes. Note also that containerization experienced the most pronounced increases on the route involving the west coast of South America.

An obvious explanation for this slow diffusion lies in the fixed costs of adoption. To make full use of containerization requires container-ready ocean liners and ports adapted to container use (specialized cranes, storage areas, and rail-heads). Building container ports typically requires large capital expenses, and will not be undertaken unless a large volume of trade can be moved through them. Similarly, shipping companies will not dedicate a container-ready ocean liner to a route unless there is a sufficient volume of trade along that route. Finally, the full benefit of containerization may not be enjoyed unless it is combined into hub and spoke systems at the regional level that allow the matching of differently sized ships to appropriate route lengths. Thus, adoption of a revolutionary shipping technology like containerization depends on the scale of trade at the level of the exporter, and the exporting route.

A third source of scale benefits lies in pro-competitive effects on pricing. Many trade routes are serviced by a small number of liner companies that have traditionally been organized in formal cartels called “liner conferences”. It is an open question as to whether these companies successfully exert market power in pricing shipping services. Some authors have used contestability theory to argue that the small number of participants is in no way indicative of their market power. However, this point has never been adequately addressed empirically, and at least one study (Fink, Mattoo, Neagu,

2002) has found evidence that freight rates are sensitive to regulatory changes meant to constrain collusive behavior by liner conferences. Supposing that freight prices do include significant monopoly markups, it is possible that increasing trade quantities would lead to entry, and a pro-competitive effect on prices.<sup>4</sup>

If scale effects operating through hub and spoke economies, specialized ships, and pro-competitive effects on prices are important, we expect to see a negative relationship between shipment quantities and measured freight rates. A fourth source of scale benefits appears only as an implicit cost of trade. Recent work by Hummels (2001) argues that lags in shipping time can be a serious deterrent to trade. He shows that each additional day lag in shipping time reduces the probability of sourcing from a particular exporter by 1%. Conditional on exporting, each additional day lag in shipping time imposes costs of 0.8% ad-valorem. By increasing quantities along a route, the frequency of ship visits rises, lowering implicit time costs of trade.

All four arguments suggest that shipping scale economies are a regional public good. That is, increases in trade between the US and Argentina benefit these partners, but also the other countries (Brazil, Venezuela, Caribbean) lying along the route. It follows from this that countries may prefer to see tariff liberalization concentrated among regional neighbors.

This paper proceeds in two main sections. First we sketch a model that describes the interaction between the scale of trade and shipping costs. In the model, a monopoly shipper decides whether to pay a fixed cost in order to adopt a lower marginal cost shipping technology. The quantity of trade along a route determines which technology is

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<sup>4</sup> There is a literature arguing, from contestability theory, that potential entry into liner routes is sufficient to keep even single service providers from charging monopoly markups. The theory has not been tested.

chosen; tariffs increase trade quantities, making it more likely that the low marginal cost technology is chosen. Liberalizing countries thus face a complementary reduction in shipping costs.

This model is consistent with the introduction of specialized vessels along a route as well as the addition of shipping capacity in order to reduce shipping lags. It is also consistent with the development of hub and spoke networks provided that the shipper in question is a monopolist able to internalize the externalities of such a network. In order to keep the model simple, we have not incorporated pro-competitive effects on freight prices, though we think these effects may be at least as important as the shipping capacity decision we highlight here. (In any case, our empirical exercise cannot distinguish the two channels.)

The model suggests two sorts of empirical analysis. First, we directly estimate the effects of shipping scale (at the level of the exporter, and the exporting route) on technology adoption and shipping frequency. We examine the adoption of containerized shipping from 1976-1995, relating it to the scale of trade. We also estimate the sensitivity of shipment frequency to shipment quantities. Combining these with Hummels (2001) estimates of time cost savings provides a second source of scale gains in shipping.

Finally, we provide an empirical analysis in which trade quantities and shipping costs are jointly determined. We estimate this joint dependence and find strong evidence for scale economies in shipping. Increasing trade quantities (at the level of shipments, aggregate bilateral trade and aggregate regional trade) reduces shipping costs. The identification strategy relies on bilateral variation in tariff rates as an exogenous

determinant of trade quantities, precisely the same policy experiment as is conducted under regional liberalization such as a FTAA.

The model and empirical analysis in the paper are entirely positive in focus. The concluding section describes some normative implications that follow. These implications include the possibility that, with route-specific scale economies in trade, selective regional liberalization may lead to greater gains from trade than broad multilateral liberalization.

## 2. Model

In this section we describe a model in which the quantity traded and the level of transportation costs is jointly determined. To focus on this interaction we consider a partial equilibrium model of trade in a homogeneous final good to keep the trade side of the model as simple as possible, and introduce a monopoly shipper that makes decisions about which technology to use and how to price transportation services. These decisions are affected by variation in parameters such as the size of the market and the tariffs set by the importer.

There are two countries, an importer and an exporter of the good. We assume that exporting firms are perfectly competitive price takers with constant marginal costs =  $p$ . The importing country has excess (import) demand for the good of

$$(1.1) \quad q = a - bp^*$$

The price that a consumer faces is the price of the good times the tariff and plus the transportation cost:

$$(1.2) \quad p^* = pt + f$$

Substituting for the price from (1.2) into (1.1) allows us to construct a derived demand for transportation services in terms of the freight rate

$$(1.3) \quad q = (a - bpt) - bf$$

For convenience denote the intercept of the transportation demand curve as  $a\text{-tilda}$ :

$$(1.4) \quad \tilde{a} = a - bpt$$

A higher tariff (or a higher goods price) represents an inward shift of the transportation demand curve. Rewriting (1.3) using (1.4) yields the inverse transportation demand curve as

$$(1.5) \quad f = \frac{\tilde{a} - q}{b}$$

The monopolist has a cost function

$$(1.6) \quad C = F + cq$$

Facing demand given by (1.5), profit maximization implies a monopoly freight rate charged to exporting firms of

$$(1.7) \quad f = \frac{1}{2} \left( \frac{\tilde{a}}{b} + c \right)$$

The price charged by the shipper depends positively on the intercept – lowering a tariff leads to a parallel outward shift in the demand for transportation services. At the initial freight price this represents a drop in the elasticity of transportation demand, and so the reduced tariff causes the monopoly markup to increase.

We can now examine the effects of a tariff reduction on the quantity imported. Given import demand and the monopoly shipper's optimal freight price we solve for the quantity imported as

$$(1.8) \quad q = \frac{1}{2}(a - bpt - bc)$$

Comparing equation (1.8) to equation (1.3) allows us to see the direct and indirect effects of tariff reductions on import quantities. If the freight price is fixed and independent of the tariff, inspection of equation (1.3) shows that any change in tariff will have an effect on the quantity of the traded goods given by  $\partial q / \partial t = -bp$ . (The higher the price of the good that is being shipped and the more elastic the demand for that good, the greater is the impact of a change in a tariff on the quantity.) Incorporating the monopolist's pricing decision in equation (1.8), we see that a tariff change has a smaller effect on import quantity  $\partial q / \partial t = -bp / 2$ . The reason is that the tariff reduction lowers the elasticity of transportation demand and causes the monopolist to charge a higher markup over marginal cost. This indirect effect operating through the markup unravels half of the tariff reduction. In other words, tariff reductions are associated with increased shipping costs.

The two technologies available to the monopoly shipping firm are

$$(1.9) \quad \begin{cases} F = 0; c > 0 \\ F > 0; c = 0 \end{cases}$$

The first technology requires no fixed costs, but has a positive marginal cost per unit shipped. The second requires a fixed payment, but has no marginal cost per unit. We choose these for simplicity, but the demonstration extends readily. One can more generally think about our setup in incremental terms – a reduction in marginal costs of  $c$  can be purchased with an incremental investment of  $F$ . Thus one can think of this choice either as a single yes/no decision on, for example, port infrastructure. Or, one can think of the choice in terms of a menu of ship sizes from which the shipper can select.

Examining the first order condition we see that, for a given tariff (and corresponding level of demand), the monopoly would charge a lower price when adopting the low marginal cost technology. The difference is given by

$$(1.10) \quad f_{lowMC} - f_{hiMC} = -\frac{c}{2}$$

Inducing the shift to the lower marginal cost technology would therefore lower trade costs and further increase trade. The simple point is that tariff reductions can increase the scale of trade to such an extent that the monopolist prefers a high fixed cost, low marginal cost shipping technology.

The technology choice in turn has an effect on the quantity traded. If the tariff reductions are insufficient to induce adoption of the high fixed cost technology then transportation prices and import quantities are given by equations (1.7) and (1.8). Quantities traded are increasing, but at a slower rate than if the freight rate were fixed. However, if tariff reductions are sufficient to induce adoption of the low marginal cost shipping technology, there is a discrete downward jump in the freight price charged. The size of the jump is given by (1.10). This has a corresponding upward jump in the quantity traded.

This model is very simple but it yields several interesting conclusions. In the single technology case (or when tariff reductions are small), tariff liberalizations result in higher shipping costs because they give greater markup power to monopolists. In fact, the monopoly shipper unravels half of a tariff reduction through increased markups.

If the choice of shipping technology is made endogenous, then sufficiently large tariff liberalizations will be reinforced by shipping cost reductions. Once the scale of

trade is large enough, the monopoly shipper complements the tariff reduction by adopting a lower marginal cost technology and consequently offering lower prices.

These two possibilities are starkly at odds, and suggest an interesting empirical question: do we see higher or lower shipping costs on heavily traded routes? If we see lower shipping costs it suggests that shippers may respond to liberalizations by adopting lower marginal cost technologies.

### **3. Empirics**

In this section we provide several exercises inspired by the underlying model. First, we examine whether changes in shipping technology are a function of the scale of trade. In particular, we analyze the adoption of containerized shipping, and the frequency of port visits. Both have the characteristic of a technology that raises fixed costs but lowers marginal costs of shipping, either explicitly (containerization) or implicitly (through time savings). Second, we examine whether these technological changes, and others we cannot measure directly, show up in lowered freight rates for heavily traded shipping routes.

In each case there is an issue of identification. Nearly any model of trade will predict causality running from trade costs to trade quantities – high shipping costs impede trade. Similarly, trade and transportation infrastructure will obviously be positively correlated (in the same sense that factory output is positively correlated with the number of workers or the capital stock that factory uses). Several papers have emphasized the strong link between the quality of domestic transportation infrastructure and trade

volumes.<sup>5</sup> These papers do not indicate which way the causality runs, nor do they address issues of scale.

Our innovation is to suggest that equilibrium trade quantities feed back on trade costs through the adoption of increasing returns to scale shipping technology. The key to the estimation strategy is using tariffs and country size variation to trace out exogenous variation in trade quantities. Scale effects on technology choice, and their corresponding effect on freight costs can then be appropriately identified.

### *3.1 Containerization*

UNCTAD's Review of Maritime Transport reports the number of container "lifts" – that is, the number of inbound and outbound containers handled by ports in each country. The RMT data span 1976-1995, with a focus on developing countries. This is an ideal period to examine. Containerization was initially introduced in the early 1960s in the US, and spread rapidly throughout OECD countries in the 1960's and 1970s. However, outside of the OECD, adoption of containerization took place in the late 1970s through the early 1990s.

The dependent variable is the (log) number of container lifts for each country  $j$ , in levels, and scaled by the value of  $j$ 's trade (imports + exports) worldwide. We regress this on the value of  $j$ 's trade, and the value of worldwide trade for countries along  $j$ 's trade routes.

Calculating the trade along  $j$ 's route is a little tricky as a country  $m$  may frequently but not always lie on the same shipping itinerary with the country  $j$  in question. Accordingly, we weight country  $m$ 's trade by the frequency with which vessels

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<sup>5</sup> See Bougheas et al (1999) and Limao and Venables (2001).

visiting  $j$  also visit  $m$ . We then sum the weighted trade values over all countries to get  $j$ 's trade "route". Our trade values may be endogenous to the use of the improved shipping technology (containers), so we instrument using  $j$ 's GDP, and the (similarly) weighted sum of GDPs for countries along  $j$ 's trade routes. We estimate with country fixed effects to isolate changes corresponding to trade growth, and include year dummies to pick up trends.

The results are displayed in Table 2. Countries with a large volume of trade use containers more intensively. Countries that expand the scale of trade via GDP growth and tariff reductions see a substantial increase in the use of a revolutionary shipping technology. However, the route effects evident in Figure 1 appear not to matter in the regression specification that includes own trade.

### *3.2 Shipment Frequency and Time Lags*

Suppose that ocean going vessels could be costlessly scaled up or down in size without sacrificing any operating efficiencies. Then the size of shipments between a country pair, or along a route, would not affect the frequency of vessel visits. One could simply utilize small ships on small scale route, large shipments on large routes, and have these ships visit daily. However, if vessel scale does matter, shippers must examine the scale of cargo available to be moved and adjust accordingly. One dimension of adjustment is adjusting vessel size. Another dimension of adjustment is adjusting the frequency of visits, that is, having a 1000 TEU containership visit once a month rather than once a week, or daily.

These adjustments can be very costly. Hummels (2002) estimates that time lags associated with shipping are equivalent to almost 1 percent of the value of the good for each day spent in shipping. Further, each additional day spent in shipping lowers the probability that a country will export a commodity by 1 percent.

In this section, we estimate the degree to which time lags are a function of the frequency of liner visits to a particular port, and in turn, a function of the scale of trade moved along a route. To identify this relationship we regress shipment times, in days, on shipment distances, the volume of trade shipped by the exporter, and the volume of trade shipped by other countries along the same route. As before, trade volumes are instrumented by exporter GDP and population, and the GDP and population of other countries along the route. The results are displayed in Table 3.

Doubling shipment distances (Australia to the US west coast is roughly twice as far as Spain to the US east coast) increases shipping times by 65 percent, or about 10 days. The elasticity on both bilateral and regional quantities is around  $-0.10$ . Increasing bilateral and regional quantities by one standard deviation relative to the mean reduces shipping times by 31 and 25 percent, respectively.

### *3.3 Freight Rates*

Finally, increases in trade scale may result in many subtle adjustments in shipping technology, as well as pro-competitive effects on prices, that we cannot estimate separately and directly. We can, however, examine the cumulative effect of trade scale on shipping prices.

Our dataset includes a cross-section of importers and exporters in 1994. We examine how trade quantities at various levels affect within-commodity variation in freight rates. The identification comes off of variation in the quantities at the commodity level, the country pair level, and the importer x region level. However, if scale economies in shipping are in some sense “shared” over these levels of aggregation, we will not be able to measure them.

Denoting importers by  $i$ , exporters by  $j$ , and commodities by  $k$ , we write ad-valorem freight rates as

$$(1.11) \quad \ln f_{ij}^k = \alpha^k + \beta_1 \ln DIST_{ij} + \beta_2 \ln q_{ij}^k + \beta_3 \ln q_{ij} + \beta_4 \ln q_{iRj} + e_{ij}^k$$

Commodity level freight rates ( $f$ ) are a function of a commodity specific intercept, which captures cross-commodity differences in weight, bulk, and handling requirements; the distance shipped, and three measures of (nominal) quantities shipped. We include the quantity of the individual commodity (measured at the 6 digit HS level) for a country pair, the aggregate quantity of bilateral trade between the country pair (for all commodities other than  $k$ ), and the (weighted) quantity of trade between the importer and exporters along  $j$ 's “route” for all exporters other than  $j$ .<sup>6</sup>

We instrument for the bilateral quantity of trade in a category  $k$  using prices ( $p$ ) and tariffs ( $TAR$ ). Following gravity models, we instrument for aggregate bilateral quantities using the output and labor force of the importer and exporter.<sup>7</sup> Similarly, we instrument for aggregate trade along a route using the weighted sum of output and workforce of countries along  $j$ 's route.

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<sup>6</sup> A country  $m$  may frequently but not always occur on the same itinerary with the exporter in question. Accordingly, we weight the trade of  $m$ 's exports to  $i$  by the frequency with which vessels visiting exporter  $j$  also visit exporter  $m$ . We then sum the weighted quantities over all exporters.

<sup>7</sup> Results are qualitatively similar using endowments rather than GDP.

The data for this exercise cover the bilateral trade of six importers (Argentina, Brazil, Chile, Paraguay, Uruguay, and the United States) with all exporters worldwide, measured at the 6 digit level of the Harmonized Classification System (5000+ categories) in 1994. We observe shipment values  $V$ , weight (WGT), the total freight bill paid ( $F$ ), and the ad-valorem tariff rate ( $t$ ). All included variables have true importer-exporter-commodity category variation. All data are expressed relative to commodity means, which subsumes differences in units across categories. Data on  $V$ , WGT, and  $F$  are taken from national data sources for the importers. Bilateral tariff rates are taken from extracts of the UNCTAD TRAINS database. Incomes and workforce data are taken from the Summers and Heston Penn World Tables data. Summary statistics for the data are included in appendix table A-1.

The results of this regression are contained in Table 4. We provide two specifications, with and without using shipment prices as instruments for quantities in the first stage. In both cases we find a negative effect of commodity level quantities on the ad-valorem freight rate, a positive effect of aggregate bilateral quantities, and a negative effect of aggregate route quantities.

The negative sign on the route quantity is the most interesting effect. A one standard deviation increase in the route quantity relative to the mean would reduce shipping costs by one-third. To put this in terms of a policy experiment, suppose regional tariffs were reduced by 10 percentage points. Using an elasticity of trade quantity with respect to price of 6, this would increase regional quantities by 60 percent. As a consequence freight rates within the region would fall by around 7 percent.

The effect of a tariff reduction on an importer-exporter pair is more difficult to calculate. A tariff reduction would increase quantities for individual commodities, lowering the freight rate, but it would also increase the aggregate quantity, pulling the freight rate back up. The net effect, summing over all commodities, will be a reduction in shipment costs. This is for two reasons. First, the negative coefficient on commodities is greater in absolute magnitude than the positive coefficient on aggregate quantities. Second, all variables here are in logs, and the sum of the log of individual shipments will exceed the log of the sum of individual shipments due to the convexity of the natural log function. We cannot calculate the precise effect without knowing all of the individual changes, but we know that it will be negative.

#### **4. Implications and Conclusions**

We show, theoretically and empirically, how lowering political barriers to trade can lead endogenously to a reduction in other trade frictions. In our model a monopoly shipper decides whether to adopt a low marginal cost technology as a function of the tariff and corresponding level of demand. Tariffs increase trade quantities, making it more likely that liberalizing countries face a complementary reduction in shipping costs.

We find direct evidence that increased trade scale improves technology, in particular, the use of containerized shipping. Increased trade scale also increases the frequency of shipping, lowering implicit time costs of trade. We also find that doubling trade quantities along a route reduces shipping costs by a 12 percent for all countries on that route, with an additional direct reduction in costs for the bilateral pair.

This paper focuses on a positive analysis of the joint determination of trade quantities and shipping costs but it suggests an interesting set of normative questions. In particular, how is the standard welfare analysis of regional trade liberalization affected by the endogeneity of shipping costs?

It is well known that the welfare gains from regional liberalization depend on transportation costs. Krugman (1991), and Frankel, Stein and Wei(1996) show that liberalizing with “natural” trading partners is more likely to be welfare enhancing because prices, inclusive of shipping, are lower for natural partners. That is, regional liberalization leads in these cases to trade creation rather than trade diversion.

This analysis supposes that trade costs are unaffected by equilibrium quantities of trade. However, if scale economies in shipping *along a particular route* are sufficiently strong, then trading partners may endogenously become natural. That is, regional liberalization boosts the quantity of bilateral trade, leading to a reduction in transportation costs.

To illustrate, consider the merits of a regional trade pact like the FTAA. In a model where freight rates are fixed exogenously Argentina and Brazil compete with each other for the US market. Each would want the US to lower tariffs selectively, excluding the other country from the block. In a world with endogenous freight rates there is a countervailing force. Argentina benefits from increased Brazilian trade with the US because this trade lowers shipping costs for Argentina as well.

Next consider the merits of liberalizing regionally through the FTAA, or pursuing multilateral negotiations through the WTO. With exogenously given shipping costs the

standard trade creation/diversion results suggest that the FTAA may or may not be beneficial. However, the first best solution is clearly to liberalize multilaterally.

The preference for multilateral liberalization is no longer obvious in a world with endogenous shipping costs. Suppose that multilateral liberalization leads European and South American exporters to share the US market. Sharing the market might lead to a volume of trade insufficient for shippers to adopt the low marginal cost shipping technology. However, liberalizing selectively through the FTAA may generate sufficient quantities along the north-south route that the shippers are willing to pay the higher fixed costs to adopt the low marginal cost technology. A consequence can be that welfare is maximized by concentrating trade along a single route, and differential tariffs provide an effective way to provide that concentration.

Of course, this logic can easily run the other way. Suppose that trade volumes pre-liberalization were high between US-Europe and low on US-South America routes. In this case, the FTAA could balance trade volumes, preventing the realization of scale gains on the North-North route.

In these cases the welfare rankings of policies will depend on a host of parameters, but the key variable is the responsiveness of shipping costs to trade quantities. We demonstrate here that the response is not negligible – political trade liberalizations can lead to a virtuous cycle of increased trade, increased investment in trade infrastructure, and further reductions in trade costs.

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## Data Appendix

### Imports and Transport Cost Data.

*US Census Bureau, "US Imports of Merchandise".* These data report extremely detailed customs information on US imports from all exporting countries (approximately 160) for 1994. The data are reported at the 10 digit Harmonized System level (approximately 15300 goods categories), which we aggregate to the 6 digit level for comparability with the other trade data. Data include the valuation of imports, inclusive and exclusive of freight and insurance charges, shipment quantity (by count and by weight), transportation mode, district of entry into the US, and duties paid. Goods are valued FAS, or "free alongside ship" meaning that freight charges include loading and unloading expenses.

*ALADI Secretariat, "Latin American Trade".* Reports imports of Argentina, Brazil, Chile, Paraguay, and Uruguay from 1994 at the 6 digit Harmonized System coding (approximately 3000 goods). Data include exporter, value of imports, weight, freight charges and insurance charges (separately). Freight charges are based on FOB ("free on board" - exclusive of loading costs") valuation of goods. For overland transport within the ALADI countries it appears that the freight field has a zero value. This is because charges are only incurred between exit and entry ports, and these are the same for overland transport. Note, however, that this does not change the relative valuation of freight charges across export partners. All trade incurs some overland shipping from factory to exporting port and from importing port to location of consumption and these costs are missing from all the data. One can then think of the observed values as a distribution that is simply shifted to the left relative to the true set of values.

## OTHER DATA

### *Distance*

The industry standard for measuring bilateral distance is the "Great Circle" straight-line distance between partner countries, which may involve polar transit or travel that intersects a continent. We improve on this in two ways. First, we use port-to-port distances constructed by forcing shipments to round continental bodies. The difference can be substantial in some cases. As an example, German goods shipped to the US east coast are approximately straight-line, whereas goods shipped to the US west coast must transit through the Panama Canal – roughly doubling the straight line distance.

We use US Census data on US District of Entry, which can be used to separate imports coming into Hawaii from those entering Miami, Boston and Los Angeles. A common complaint with Census data on US district of entry (for imports) or exit (for exports) is that these districts do not necessarily capture the ultimate US consumer or the original US producer of traded goods. This is not a concern here as we are primarily interested in the measured cost of freight in getting the goods to the entry point where customs officials stop calculating freight charges.

### *Tariff Data*

Bilateral tariff data at the 6 digit HS level are available for the six importers. While the precise year varies somewhat across countries, most of the data are from 1994. The data originally come from the TRAINS dataset, and we employ a special extract provided by Jon Haveman that painstakingly constructed bilateral tariff rates using preference indicators in these data.

### *Shipping Schedule*

Data on ocean shipping times are derived from a master schedule of shipping for 1999 taken from [www.shipguide.com](http://www.shipguide.com). This shipping schedule describes all departures and arrivals of all commercial vessels operating worldwide in this period. From this, we construct a matrix of shipping times between all ports everywhere in the world and all US entry ports. Several modifications are necessary. First, direct shipments are not available for every port-port combination (Tunis does not ship directly to Houston). In these cases, I calculate all possible combinations of indirect routings (Tunis to Rotterdam to Houston; Tunis to Rio to Houston and so on) and take the minimum shipment time available through these routings. Second, there are generally multiple ports within each origin country. In this section, a within-country average of shipment time from these ports is employed. Because US data include entry port detail, these are combined with destination-port specific arrival times.

Table 1 – Liner Vessel Itineraries

<b>Mediterranean Shippi, USASA service</b>		<b>Libra, ASANG service</b>	
<b>Chiara, voyage 487A</b>		<b>TMM Guadalajara, voyage 4</b>	
<b>Location</b>	<b>Date</b>	<b>Location</b>	<b>Date</b>
Veracruz, Mexico	Thu Jun 6	Buenos Aires, Argentina	Sun Jun 9
Altamira, Mexico	Sat Jun 8	Itajai, Brazil	Wed Jun 12
Houston, TX USA	Sun Jun 9	Santos, Brazil	Fri Jun 14
New Orleans, LA USA	Tue Jun 11	Rio de Janeiro, Brazil	Sun Jun 16
Freeport, Bahamas	Tue Jun 18	Puerto Cabello, Venezuela	Sun Jun 23
Cartagena, Colombia	Sat Jun 22	Veracruz, Mexico	Sat Jun 29
Buenaventura, Colombia	Mon Jun 24	Altamira, Mexico	Sun Jun 30
Callao, Peru	Fri Jun 28	Houston, TX USA	Tue Jul 2
Guayaquil, Ecuador	Fri Jun 28	New Orleans, LA USA	Thu Jul 4
Arica, Chile	Mon Jul 1		
Antofagasta, Chile	Tue Jul 2		
Valparaiso, Chile	Wed Jul 3		
Talcahuano, Chile	Mon Jul 8		

Table 2. Adoption of Containerization

Dependent variable <sup>2</sup>	Volume of trade <sup>3</sup> :		N-obs.
	country	route weighted	
Container lifts	11.16 (4.75)	-0.02 (0.08)	597
Container lifts/ trade value	2.73 (0.93)	0.001 (0.016)	597

Notes:

<sup>1</sup> - All variables are in logs and mean differenced by country.

<sup>2</sup> - Both regressions include year fixed effects.

<sup>3</sup> - Volumes of trade are instrumented by corresponding GDPs.

Table 3 - Trade Scale and Time Lags in Shipping

	Dep var: Time to US	
Distance shipped	0.64 (-0.02)	0.56 (-0.02)
Exporter Trade Quantity	-0.1 (-0.01)	-0.12 (-0.01)
Route Trade Quantity	-0.09 (-0.02)	--
Obs	1191	1191

Notes:

1. All variables in logs, standard errors in parentheses.
2. Instruments: GDP, workforce of exporter, route

Table 4 – Scale Economies in Transport

Dep var	Instruments	Bilateral Commodity Quantity	Bilateral Aggregate Quantity	Route Aggregate Quantity	$DIST_{ij}$	N.obs
Ln(freight)	(a)	-0.32	0.21	-0.12	0.32	231311
		-0.0089	-0.0073	-0.0023	-0.0026	
Ln(freight)	(b)	-0.23	0.17	-0.13	0.31	224784
		-0.008	-0.0066	-0.002	-0.0024	

$$(1.11) \quad \ln f_{ij}^k = a^k + \beta_1 \ln DIST_{ij} + \beta_2 \ln q_{ij}^k + \beta_3 \ln q_{ij} + \beta_4 \ln q_{iRj} + e_{ij}^k$$

Notes

1. All variables are in logs, standard errors in parentheses
2. Instruments:
  - (a) Importer and exported incomes and workforce, tariffs, regional weighted incomes
  - (b) All instruments above, plus prices

Appendix Table – Summary statistics of the variables.

Variable	Unit	Statistic	
		Mean	Standard deviation
Ad valorem freight rate		0.12	0.16
Distance	Km	9,064	4,853
Exporter's labor force	,000	51,168	126,750
Exporter's GDP	\$, billion	1,080	1,790
Importer's labor force	,000	58,431	56,389
Importer's GDP	\$, billion	2,820	3,330
Route weighted labor force	,000	15,079	46,982
Route weighted GDP	\$,billion	379	809
Commodity level trade volume	\$,000	2,439	73,000
Bilateral volume of trade	\$, billion	7	21
Route weighted volume of trade	\$, 000	1,690	4,010

Figure 1 – Share of Containerization by Trade Route

