Lumpy Trade and the Welfare Effects of Administrative Barriers*

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Abstract

Using detailed U.S. and Spanish export data, we document that administrative trade costs of per shipment nature (documentation, customs clearance and inspection) lead to less frequent and larger-sized shipments, i.e. more lumpiness, in international trade. We build a model to analyze these effects and their welfare consequences. Exporters decide not only how much to sell at a given price, but also how to break up total trade into individual shipments. Consumers value frequent shipments, because they enable them to consume close to their preferred dates. Having fewer shipments hence entails a welfare cost. Calibrating the model to observed shipping frequencies and per-shipment costs, we show that countries would gain 2–3 percent of their GDP by eliminating such barriers. This suggests that trade volumes alone are insufficient to understand the gains from trade.

Keywords: administrative trade barriers, shipments, welfare

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1 Introduction

With the diminishing use of tariff-type trade restrictions, the focus of trade policy has been increasingly shifted towards less standard sorts of trade barriers, including administrative barriers to trade. We define administrative barriers as bureaucratic procedures ("red tape") that a trading firm has to get through when sending a good from one country to the other. A large part of such trade barriers are costs that accrue per each shipment, such as filling in customs declaration and other forms, or having the cargo inspected by health and sanitary officials.

The magnitudes of per-shipment trade costs, such as document preparation and customs administration, are sizeable. According to the World Bank's *Doing Business* survey, in a typical U.S. export transaction, these two tasks take 18 working days and cost $700 (most of the costs occurring in the importing country). The same figures for a typical Spanish export transaction are 20 days and $850. There is large variation by destination country. Completing the documentation and customs procedures of an import transaction in Singapore takes only 2 days, in Venezuela 2 months (Table 1).

Table 1: Costs of trade documentation and customs procedure

	Time cost (days)	Monetary cost (U.S.$)
In exporter country		
U.S.	3	250
Spain	5	400
In importer country		
median	15	450
minimum	2	92
maximum	61	1830

Notes: Data is from the Doing Business survey 2009 for 170 countries.

The starting point of our paper is a tradeoff between per-shipment trade costs and shipping frequency. In the presence of per-shipment costs, exporters would want to send fewer and larger shipments. However, an exporter waiting to fill a container before sending it off or choosing a slower transport mode to accommodate a larger shipment sacrifices timely delivery of goods and risks losing orders to other, more flexible (e.g., local) suppliers. Similarly, holding large inventories between shipment arrivals incurs substantial costs and prevents fast and flexible adjustment of product attributes to changing consumer tastes. Moreover, certain products are storable only to a limited extent or not at all. With infrequent shipments a supplier of such products can compete only for a fraction of consumers in a foreign market.

We provide empirical evidence using transaction-level export data from the U.S. and Spain on the responsiveness of shipping frequency and shipment size to per-shipment costs. We capture per-shipment administrative barriers as the sum of the costs of documentation and customs administration (either time or monetary costs) in the importing country. We introduce a novel decomposition of destination-specific trade flows into five margins, including the number of shipments and the physical shipment size. The decomposition takes into account that a large amount of variation in the shipment size occurs between transport modes and product types. We run gravity-like regressions for each margin, where we adopt the method of Baier and Bergstrand (2009) for a theory-consistent specification. The results confirm that both the U.S. and Spain exports fewer and larger-sized shipments to countries with larger administrative costs of importing.

We build a model to explain the above findings and further explore their implications. Exporters decide not only how much to sell at a given price, but also how to break up total trade into individual shipments. Shipments are located on a circle, representing time points in a year, in the spirit of Salop (1979). When per-shipment trade costs are higher, firms will choose to send fewer, but potentially larger shipments. Consumers value frequent shipments, because they enable them to consume close to their preferred dates. Having fewer shipments hence entails a welfare cost, even holding the total volume of trade and import penetration fixed.

Our model features a new margin of welfare effects of trade barriers, in particular, of per-shipment trade costs. Recently, Arkolakis, Costinot and Rodriguez-Clare (2012) have shown that, in a wide class of models, all welfare effects of trade can be succinctly summarized by a sufficient statistic: how much does import penetration change with trade barriers? Two conclusions emerge from this: First, trade barriers have small welfare costs.[1] Second, the peculiarities of trade models do not matter much for the magnitude of welfare costs. Our contribution suggests an additional source of welfare costs and accommodates welfare effects under unchanged import penetration.

How important are the welfare costs of less frequent shipments? To answer this question, we conduct counterfactual exercises in a calibrated version of our model. We calibrate our model to match the key moments of our reduced-form estimates. The overall elasticity of trade volumes to trade costs is governed by the price elasticity of demand and can be estimated in standard ways. We infer the preference for timely shipments from the elasticity of shipment frequency to per-shipment costs. Intuitively, if consumers care much about timely delivery, then firms will ship as frequently as they can, and shipping frequency is not very sensitive to per-shipment costs.

We then report how welfare would change in a country if it eliminated the per-shipment administrative barriers. The median country would gain 2–3 percent of consumption-equivalent with such trade liberalization. There is also a wide distribution of these welfare gains. Countries at the 90th percentile would gain 4–7 percent. This is in contrast to the gains from trade estimated by, for example, Alvarez and Lucas (2007) to be of the order of 1 percent of GDP. That is, administrative barriers are responsible for a sizeable share of the welfare costs of trade.

Our emphasis on shipments as a fundamental unit of trade follows Armenter and Koren (2010), who discuss the implications of the relatively low number of shipments on empirical models of the extensive margin of trade.

We relate to the recent literature that challenges the dominance of iceberg trade costs in trade theory, such as Hummels and Skiba (2004) and Irarrazabal, Moxnes and Opromolla (2010). They argue that a considerable part of trade costs are per unit costs, which has important implications for trade theory. Per unit trade costs do not necessarily leave the within-market relative prices and relative demand unaltered,

[1] Eaton and Kortum (2002) and Alvarez and Lucas (2007) report welfare gains in the order of 1 percent of GDP.

hence, welfare costs of per unit trade frictions can be larger than those of iceberg costs.[2]

The importance of per-shipment trade costs or, in other words, fixed transaction costs has recently been emphasized by Alessandria, Kaboski and Midrigan (2010). They also argue that per-shipment costs lead to the lumpiness of trade transactions: firms economize on these costs by shipping products infrequently and in large shipments and maintaining large inventory holdings. Per-shipment costs cause frictions of a substantial magnitude (20% tariff equivalent) mostly due to inventory carrying expenses. We consider our paper complementary to Alessandria, Kaboski and Midrigan (2010) in that we exploit the cross-country variation in administrative barriers to show that shippers indeed respond by increasing the lumpiness of trade. On the theory side, we focus on the utility loss consumers face when consumption does not occur at the preferred date. Moreover, our framework also applies to trade of non-storable products.

Our approach is also related to the literature on the time cost of trade, which argues that time in trade is far more valuable than what the rate of depreciation of products or the interest cost of delay would suggest (Hummels and Schaur, 2012; Djankov, Freund and Pham, 2010). A series of papers look at the implications of the demand for timeliness on production location and transport mode choice (Harrigan and Venables, 2006; Evans and Harrigan, 2005; Harrigan, 2010). When timeliness is important, industries tend to agglomerate and firms source from nearby producers even at the expense of higher wages and prices. Faraway suppliers have comparative advantage in goods that are easily transported by fast air transportation.

A more policy-oriented line of literature is centered around the notion of "trade facilitation," i.e., the simplification and harmonization of international trade procedures. This line of literature provides ample evidence through country case studies,

[2]Hummels and Skiba (2004) obtain an interesting side result on a rich panel data set, which is consistent with the presence of per-shipment costs. The per unit freight cost depends negatively on total traded quantity. Hence, the larger the size of a shipment in terms of product units, the less the per-unit freight cost is.

gravity estimations and CGE model simulations on the trade-creating effect of reduced administrative burden.[3]

The paper is structured as follows. Section 2 describes the database and measurement issues. Section 3 presents the estimation. Section 4 builds a model of shipping frequency and Section 5 presents a welfare analysis. Section 6 concludes.

2 Data and measurement

We describe data for per-shipment administrative trade barriers and transaction-level trade flows. Then we report evidence for trade lumpiness in the U.S. and Spain.

2.1 Per-shipment administrative barriers to trade

We capture administrative trade barriers in the destination country with indicators on the time required for and on the monetary costs associated with import documentation, customs clearance, and inspection. Data is from the *Doing Business* survey of the World Bank.[4] The indicators are country-specific and do not vary with the trading partner or across products.

The survey is carried out among trade facilitators at large freight-forwarding companies. The majority of world trade is done via freight forwarders and trade facilitators are well informed about the transaction procedures. The survey questions refer to a standardized containerized cargo of goods shipped by sea.[5] Since data is specific to ocean transport, controlling for the transport mode in the analysis will be important.

[3]An assessment of estimates shows that trade facilitation can decrease trade costs by at least 2% of the trade value, and this number may get as large as 5-10% for less developed countries. For more see e.g. Engman (2005) or Francois, van Meijl and van Tongeren (2005).

[4]We use the survey from 2009. Detailed survey data is not available publicly from earlier surveys. Nevertheless, survey figures appear to be strongly persistent over time.

[5]The traded product is assumed to travel in a dry-cargo, 20-foot, full container load via ocean. It weighs 10 tons, is valued at USD 20,000, is not hazardous and does not require special treatment or standards. (http://www.doingbusiness.org/MethodologySurveys/TradingAcrossBorders.aspx)

The survey differentiates among four procedures: document preparation, customs clearance and inspection, port and terminal handling, and inland transportation and handling from the nearest seaport to the final destination. The time to complete a procedure is expressed in calendar days, the monetary cost in U.S. dollars per container. Monetary costs include various fees and charges, but exclude customs tariffs, trade taxes or bribes.

We take the sum of the indicators for document preparation and customs clearance and inspection as our indicator for administrative barrier. The sum of the indicators for the other two procedures, which are more closely related to moving and storing the cargo, will be used as control variable.

Table 2: Time and monetary costs of four import procedures

	Time cost (days)			Monetary cost (US$)		
Procedure	Mean	% of total	CV	Mean	% of total	CV
Document preparation	13.7	51.7	0.75	306	19.0	0.61
Custom clearance and inspection	3.7	14.0	0.74	214	13.2	0.97
Port and terminal handling	4.5	16.8	0.74	317	19.6	0.56
Transportation from seaport	4.7	17.5	1.56	778	48.2	1.08
Total	26.6	100.0	0.69	1615	100.0	0.63

Note: Own calculations based on Doing Business data from 2009. Time and monetary cost of the four procedures of an import transaction. Statistics for 170 countries. CV is coefficient of variation (standard deviation over the mean).

It appears that administrative barriers are somewhat better represented by the amount of time lost than by a monetary measure. In particular, document preparation is the most time-consuming out of the four procedures (Table 2). In terms of monetary costs, transportation from the seaport is the most burdensome. Interestingly, the time and the monetary cost measures of administrative barriers are only moderately correlated. The correlation coefficient is 0.39.

2.2 Trade transactions and their lumpiness

We examine disaggregated data on exports from the U.S. and Spain to a large set of countries in 2005. We want to look at the lumpiness of trade transactions, i.e., how frequently the same good is exported to the same destination country within the year, as well as the typical size of a shipment.

This exercise requires transaction-level (shipment-level) trade data. Customs Bureaus in both the U.S. and Spain record trade flows at the shipment level. The Spanish database is made publicly available at this same level, whereas the U.S. database is somewhat aggregated up. An entry in the publicly available U.S. Foreign Trade statistics reported by the Census Bureau is differentiated by product, country of destination, month of shipment, and shipping Census region. Most importantly, the dataset also reports the number of shipments aggregated in each entry, so we can precisely measure not only the total number of shipments to a destination, but also how it varies across products and modes of transport. More than half of the entries contain only one shipment, and the average number of shipments per entry is only four. In both databases, the identity of the exporting firm is omitted for confidentiality reasons. A more detailed data description is in Appendix A.

We consider 170 destination countries for the U.S. and 166 (143 non-EU) destinations for Spain. Product classification is very detailed in both cases, covering around 8,000 different product lines (10-digit Schedule B in the U.S. and 8-digit Combined Nomenclature in the Spanish case). In the case of U.S. exports, which is not a shipment-level database, we can calculate the value of a shipment per each cell by dividing the trade value with the number of shipments in that cell. Similarly, physical shipment size is trade quantity divided by the number of shipments.

Tables 3 and 4 report descriptive statistics for the U.S. and Spain, respectively. In both cases four-four importers are selected that are relatively important trading partners and are countries with either low or high administrative barriers to import.

The first columns shows the value of the median shipment in U.S. dollars, calculated from the most disaggregated data (the number of entries is almost 3 million for both exporters). U.S. statistics are weighted by the number of shipments per entry. The value of the typical export shipment is $15,200 in the US, which is 28% larger than the typical shipment value in Spain.[6] Shipment sizes for selected individual destinations range between $9,000 (Spain to Australia) and $24,500 (US to

[6] We believe, this cannot be an artifact of statistical reporting requirements, because we used the same threshold value to drop low-value shipments in both databases.

Table 3: Lumpiness in U.S. exports

importer	median shipment value (US$)	how many times good shipped in a month	fraction of months in year good shipped	days to complete doc.&customs procedure
Selected low per-shipment cost importers				
Canada	14515	14.1	1.00	5
Germany	16452	2.0	0.64	4
Israel	17864	1.3	0.36	6
Singapore	17275	1.6	0.55	2
Selected high per-shipment cost importers				
Chile	12422	1.3	0.36	15
China	24540	1.9	0.64	19
Russia	21705	1.0	0.18	29
Venezuela	19405	1.4	0.36	61
All 170 importers	15200	1.2	0.27	15

Note: U.S. exports to 170 importers in 2005 with 7917 ten-digit product categories. Shipment size is the frequency-weighted median of data points at the highest-level of disaggregation. N=2993218. Shipment frequency statistics are for the median product. Trade in raw materials and low-value shipments (<USD 2500) excluded. Days to complete documentation and customs procedures is from the Doing Business database for 2009.

Table 4: Lumpiness in Spanish exports

importer	median shipment value (US$)	how many times good shipped in a month	fraction of months in year good shipped	days to complete doc.&customs procedure
Selected low per-shipment cost importers				
Australia	8981	1.0	0.17	4
France	12238	1.8	0.92	0[a]
Germany	12810	1.4	0.67	0[a]
USA	14316	1.5	0.33	3
Selected high per-shipment cost importers				
Algeria	13494	1.0	0.17	16
China	21848	1.0	0.17	19
Russia	12308	1.3	0.25	29
South Africa	13906	1.0	0.17	18
All 166 importers	11842	1.0	0.17	15

Note: Spanish exports to 143 non-EU and 23 EU importers in 2005 in 8234 eight-digit product lines. N=2937335. Shipment value is the median of individual shipments, converted to U.S. dollars with monthly average USD/EUR exchange rates. Shipment frequency statistics are for the median product. Trade in raw materials and low-value shipments (<EUR 2000) excluded. Days to complete documentation and customs procedures is from the Doing Business database for 2009. [a] Imposed for intra-EU.

China). These differences may depend on several factors, such as the nature of the exported products and the transport mode, which we will account for in the regression analysis.[7]

Trade transactions for a given product to a given destination show strong signs of lumpiness. If a product is exported to a given destination in a given month, then it is shipped typically only one or two times within that month (second columns). The strong US–Canada trade relationship is an exception with 14 shipments per month. Trade is positive in a relatively small fraction of the months within a year (third columns). The U.S. sends a product to a given destination in 3, Spain in only 2 out of the 12 months. Both statistics show a somewhat stronger lumpiness in Spanish than in U.S. exports. These figures are comparable to those reported by Alessandria, Kaboski and Midrigan (2010) for monthly U.S. imports during 1990-2005. These authors also demonstrate that lumpiness is not driven by seasonality and that it is pervasive across different types of traded goods.

3 Evidence on administrative barriers and the margins of trade

We want to see how the frequency and the size of shipments vary with the level of administrative barriers. First, we estimate product- and transport mode-level regressions. Then, we develop a decomposition of destination-specific aggregate export flows and run estimation on the aggregates. The latter method also allows for observing responses of the transport mode choice and the export product mix to administrative barriers.

[7] Sea and ground transport modes accommodate much larger weight-to-value shipments than air transportation. We report both value and physical shipment sizes by mode in Table B.1.

3.1 Product-mode-level estimation

We create databases of exports by product and transport mode (air, sea, ground) to 170 importers for the U.S. and 143 importers (EU members excluded)[8] for Spain and decompose the value of exports of product g by mode m to country j as

$$X = h\bar{n}v = h\bar{n}pq, \tag{1}$$

where we omitted the jgm subscripts. h is the number of months in the year product g is exported by mode m to country j, $\bar{n}$ is the average number of shipments per month with positive trade for a given j, g and m and v is the corresponding average shipment value, which can be further decomposed into price, p, and physical shipment size, q. Both h and $\bar{n}$ are margins of shipment frequency. Looking at h separately tells us whether the concentration of shipments in relatively few months is also responsive to administrative barriers.

We estimate by simple OLS with product-mode dummies. The dependent variable is the logarithm of either exports or one of the elements of decomposition (1). The estimating equation, with the log of exports as dependent variable, is

$$\ln X_{jgm} = \beta \cdot \text{admin}_j + \gamma \cdot \text{other regressors}_j + \nu_{gm} + \epsilon_{jgm}. \tag{2}$$

admin_j is the importer-specific administrative barrier variable with coefficient β. It is either the time cost (in days) or the logarithm of the monetary cost. Other regressors are those typically used in gravity estimations: log of GDP and GDP per capita[9], log of geographical distance from the U.S. or Spain, dummies for being landlocked or an island, Free Trade Agreement and Preferential Trade Agreement, common language and colonial relationship with the U.S. or Spain, and the sum of the other two *Doing*

[8]Destination countries in the U.S. and Spanish sample are listed in Table B.2. We exclude EU members from the Spanish sample, because the administrative barriers indicators are not relevant for intra-EU trade.

[9]GDP per capita also serves as a proxy for the overall institutional quality of the importer. This way we can ensure that the administrative burden variable does not pick up effects from other elements of institutional quality, with which it may be highly correlated.

Business import cost indicators (port handling + transport from seaport). The ν_{gm} are product-mode dummies and ϵ_{jgm} is the error term.[10]

To have a unique quantity measure, we restrict the U.S. sample to those observations where quantity is reported in kilograms. Since weight in kilograms is reported for all air- or ocean-transported shipments, we need to exclude only part of the ground-transported trade, overall 4.5% of the U.S. sample.[11]

Tables 5 and 6 present the estimated β coefficients for the time and the monetary administrative cost, respectively. Consistent with the decomposition, the coefficient estimates in the second to fourth rows in all the result tables sum up to the coefficient estimate in the first row, and the estimate in the fourth row (value shipment size) is the sum of the estimates in the fifth and sixth rows (physical shipment size and price). Robust standard errors are clustered by importer and 2-digit product group.

We find that, within product and transport mode, the shipment size increases with administrative barriers. If completing the administrative tasks takes one day longer, the value of a shipment is on average 0.2-0.3% larger. This is mostly the result of a larger physical shipment size and less of a larger price per kilogram.

We also find evidence on a negative response of the shipment frequency. Larger administrative barriers tend to coincide with more lumpiness of trade for a given product and transport mode. Both the number of months with trade and the average number of shipments per month tend to be lower in destinations with higher administrative costs. This effect is however absent for monetary costs in the case of Spanish exports.

3.2 A decomposition of aggregate exports

We develop a decomposition of destination-specific aggregate exports into five margins. These are the shipment extensive margin, the price, the (within-product-mode) physical shipment size, the transport mode, and the product composition margins.

[10]We do not account for zeros in trade and, hence, adjustment at the product extensive margin. The aggregate specification in Section 3.3 accounts for zeros.

[11]Ground-transported trade is mostly with Canada and Mexico. We check how excluding these two importers alters the results. Estimation results without Canada and Mexico (available on request) are qualitatively the same as the reported ones.

Table 5: Product-level estimates, Time cost

Dependent variable	β estimate	Robust s.e.	Adj.R^2
Exporter is U.S.			
log export	-0.003	[0.002]	0.41
log number of months	-0.003**	[0.001]	0.38
log shipment per month	-0.002***	[0.001]	0.38
log value shipment size	0.002***	[0.000]	0.38
log physical shipment size	0.001	[0.001]	0.68
log price	0.001**	[0.001]	0.73
Number of observations	400096		
Number of clusters	10934		
Number of product-mode effects	18060		
Exporter is Spain			
log export	0.000	[0.001]	0.43
log number of months	-0.002***	[0.000]	0.36
log shipment per month	-0.001***	[0.000]	0.43
log value shipment size	0.003***	[0.001]	0.45
log physical shipment size	0.002**	[0.001]	0.74
log price	0.001**	[0.001]	0.79
Number of observations	117544		
Number of clusters	7126		
Number of product-mode effects	15893		

Note: OLS estimation of (2) separately for each margin in (1) on a sample of U.S. (Spanish) exports to 170 (143) countries in 10-digit HS (8-digit CN) products in 2005. Transport mode is air, sea, or ground. Product-mode fixed effects included. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and time to complete port/terminal handling and transport from nearest seaport. Clustered robust standard errors with country and 2-digit product clusters. * significant at 10%, ** 5%; *** 1%.

Table 6: Product-level estimates, Log monetary cost

Dependent variable	β estimate	Robust s.e.	Adj.R^2
	Exporter is U.S.		
log export	-0.202***	[0.036]	0.41
log number of months	-0.127***	[0.015]	0.38
log shipment per month	-0.089***	[0.014]	0.38
log value shipment size	0.014	[0.012]	0.38
log physical shipment size	0.020	[0.016]	0.68
log price	-0.006	[0.009]	0.73
Number of observations	400096		
Number of clusters	10934		
Nr of product-mode effects	18060		
	Exporter is Spain		
log export	0.044**	[0.022]	0.43
log number of months	0.004	[0.012]	0.36
log shipment per month	0.021***	[0.006]	0.43
log value shipment size	0.019	[0.012]	0.45
log physical shipment size	0.038**	[0.015]	0.74
log price	-0.019*	[0.010]	0.79
Number of observations	117544		
Number of clusters	7126		
Nr of product-mode effects	15893		

Note: OLS estimation of (2) separately for each margin in (1) on a sample of U.S. (Spanish) exports to 170 (143) countries in 10-digit HS (8-digit CN) products in 2005. Transport mode is air, sea, or ground. Product-mode fixed effects included. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and cost to complete port/terminal handling and transport from nearest seaport. Clustered robust standard errors with country and 2-digit product clusters. * significant at 10%, ** 5%; *** 1%.

The five margins separate five possible ways of adjustment. In response to higher administrative barriers firms may reduce the number of shipments, increase the price, pack larger quantities of goods in one shipment, switch to a transport mode that allows larger shipments, or change the export product mix towards products that are typically shipped in large shipments.

Let g index products, m modes of shipment (air, sea, ground), and j importer countries. Let country 0 be the benchmark importer (the average of all of the importers in the sample), for which the share of product-level zeros are the lowest. In fact, we want all products to have nonzero share, so that the share of different modes of transport are well defined for the benchmark country.[12]

Let n_{jgm} denote the number of shipments of good g through mode m going to country j. Similarly, q_{jgm} denotes the average shipment size for this trade flow in quantity units, p_{jgm} is the price per quantity unit. We introduce the notation

$$s_{jgm} = \frac{n_{jgm}}{\sum_k n_{jgk}}$$

for the mode composition of good g in country j, and

$$s_{jg} = \frac{\sum_k n_{jgk}}{\sum_l \sum_k n_{jlk}}$$

for the product composition of country j. We define s_{0gm} and s_{0g} similarly for the benchmark (average) importer.

We decompose the ratio of total trade value (X) to country j and the benchmark country,

$$\frac{X_j}{X_0} = \frac{\sum_g \sum_m n_{jgm} p_{jgm} q_{jgm}}{\sum_g \sum_m n_{0gm} p_{0gm} q_{0gm}} = \frac{n_j \sum_g s_{jg} \sum_m s_{jgm} p_{jgm} q_{jgm}}{n_0 \sum_g s_{0g} \sum_m s_{0gm} p_{0gm} q_{0gm}},$$

[12]Note that the mode of transport will not be well defined for a product/country pair if there are no such shipments. This will not be a problem because this term will carry a zero weight in the index numbers below.

as follows,

$$\frac{X_j}{X_0} = \frac{n_j}{n_0} \cdot \frac{\sum_g s_{jg} \sum_m s_{jgm} p_{jgm} q_{jgm}}{\sum_g s_{jg} \sum_m s_{jgm} p_{0gm} q_{jgm}} \cdot \frac{\sum_g s_{jg} \sum_m s_{jgm} p_{0gm} q_{jgm}}{\sum_g s_{jg} \sum_m s_{jgm} p_{0gm} q_{0gm}} \cdot \frac{\sum_g s_{jg} \sum_m s_{jgm} p_{0gm} q_{0gm}}{\sum_g s_{jg} \sum_m s_{0gm} p_{0gm} q_{0gm}} \cdot \frac{\sum_g s_{jg} \sum_m s_{0gm} p_{0gm} q_{0gm}}{\sum_g s_{0g} \sum_m s_{0gm} p_{0gm} q_{0gm}}.$$

The first term is the shipment extensive margin. It shows how the number of shipments sent to j differs from the number of shipments sent to the average importer. The ratio is greater than 1 if more than average shipments are sent to j. The second term is the price margin. It shows how much more expensive is the same product shipped by the same mode to country j, relative to the average importer. The third term we call the *within* physical shipment size margin. It tells how physical shipment sizes differ in the two countries for *the same product and mode of transport.* The fourth term is a mode of transportation margin. If it is greater than 1, transport modes that accommodate larger-sized shipments (sea, ground) are overrepresented in j relative to the benchmark. The last term is the product composition effect. It shows to what extent physical shipment sizes differ in the two countries as a result of differences in the product compositions. If bulky items and/or items that typically travel in large shipments are overrepresented in the imports of j, the ratio gets larger than 1.

We express the same decomposition identity simply as

$$X_{j,\text{total}} = X_{j,\text{extensive}} \cdot X_{j,\text{price}} \cdot X_{j,\text{within}} \cdot X_{j,\text{transport}} \cdot X_{j,\text{prodcomp}}. \tag{3}$$

If administrative trade barriers make firms send less and larger shipments, one should see the shipment extensive margin to respond negatively and the *within* physical shipment size margin positively to larger administrative costs. If increasing the shipment size involves a change in the transport mode or the product mix, the last two margins also respond positively.

3.3 Country cross-section estimations

Naive gravity. We run simple cross section regressions with the log of the elements of decomposition (3) on the left-hand side. The estimating equation is

$$\log X_{j,z} = \beta \cdot \text{admin}_j + \gamma \cdot \text{other regressors}_j + \nu + \eta_j, \qquad (4)$$

where subscript z denotes the different margins, ν is a constant and η_j is the error term. The regressors are the same as in the product-level estimation. We estimate (4) with simple OLS and robust standard errors in the case of total exports. In the case of the five margins, we exploit the correlatedness of the errors and apply Seemingly Unrelated Regressions Estimation (SURE). The Breusch-Pagan test always rejects the independence of errors.

We report the β estimates in Tables 7 and 8. By construction, the coefficients from the five margin regressions sum up to the coefficient from the total export regression. The sum of the price and the within margins is the value shipment size. We report Wald test statistics for the significance of the sum of these two coefficients.

The signs of the coefficient estimates are in most of the cases the expected, though only some of them are statistically significant. The strongest result is a significant positive response of the shipment size to administrative costs. There is also evidence of a negative response on the shipment extensive margin, though it is statistically significant only in the Spanish sample for time costs. We find no significant effects on either the transport mode or the product composition margins.

Theory-consistent gravity. So far we have estimated an atheoretical gravity equation. Here we derive and estimate a reduced-form gravity, which is consistent with the theory of Anderson and van Wincoop (2003). Importantly, it controls for trade barriers of the importer with all the countries in the world, i.e. for multilateral trade resistance (MTR). Anderson and van Wincoop (2003) show that trade flows only depend on relative (bilateral to multilateral) trade barriers and gravity equations, which do account for that, yield biased estimates on the effects of trade barriers on trade flows.

Table 7: Simple cross section estimates, Time cost

Dependent variable	β estimate	s.e.	Adj./Pseudo R^2
	Exporter is U.S.		
log total export	0.000	[0.007]	0.85
log shipment extensive	-0.007	[0.008]	0.85
log price	-0.001	[0.002]	0.05
log within physical size	0.007***	[0.003]	0.39
log transport mode	0.001	[0.001]	0.33
log product composition	0.000	[0.002]	0.14
Number of observations	170		
Test $\beta_{price}+\beta_{within}$=0	$\chi^2(1)$=5.28, p-val=0.022		
Breusch-Pagan test	$\chi^2(10)$=73.97, p-val=0.000		
	Exporter is Spain		
log total export	-0.011	[0.008]	0.89
log shipment extensive	-0.015**	[0.006]	0.91
log price	0.003	[0.002]	0.18
log within physical size	0.003	[0.004]	0.24
log transport mode	-0.001	[0.001]	0.07
log product composition	-0.001	[0.003]	0.13
Number of observations	143		
Test $\beta_{price}+\beta_{within}$=0	$\chi^2(1)$=3.34, p-val= 0.067		
Breusch-Pagan test	$\chi^2(10)$=75.95, p-val=0.000		

Note: OLS estimation of (4) with robust standard errors for total exports, SURE for the margins, on a cross section of importers. Pseudo R^2 is for SURE. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and time to complete port/terminal handling and transport from nearest seaport. Breusch-Pagan test is for residual independence in SURE. * significant at 10%, ** 5%; *** 1%.

Table 8: Simple cross section estimates, Log monetary cost

Dependent variable	β estimate	s.e.	Adj./Pseudo R^2
	Exporter is U.S.		
log export	0.011	[0.182]	0.86
log number of shipments	-0.058	[0.144]	0.86
log price	-0.078**	[0.032]	0.09
log physical shipment size	0.113**	[0.049]	0.37
log mode composition	0.000	[0.020]	0.33
log product composition	0.034	[0.047]	0.15
Number of observations	170		
Test $\beta_{price}+\beta_{physicalsize}$=0	$\chi^2(1)$=0.56, p-val=0.455		
Breusch-Pagan test	$\chi^2(10)$=68.73, p-val=0.000		
	Exporter is Spain		
log export	-0.020	[0.162]	0.89
log number of shipments	-0.016	[0.122]	0.91
log price	0.017	[0.046]	0.16
log physical shipment size	0.048	[0.084]	0.24
log mode composition	0.006	[0.028]	0.07
log product composition	-0.075	[0.052]	0.15
Number of observations	143		
Test $\beta_{price}+\beta_{physicalsize}$=0	$\chi^2(1)$=0.93, p-val= 0.336		
Breusch-Pagan test	$\chi^2(10)$=72.58, p-val=0.000		

Note: OLS estimation of (4) with robust standard errors for total exports, SURE for the margins, on a cross section of importers. Pseudo R^2 is for SURE. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and cost to complete port/terminal handling and transport from nearest seaport. Breusch-Pagan test is for residual independence in SURE. * significant at 10%, ** 5%; *** 1%.

Our empirical specification follows Baier and Bergstrand (2009).[13] They propose a first-order log-linear Taylor series approximation of the non-linear MTR expressions around an equilibrium with symmetric trade frictions, i.e. when all bilateral trade costs are equal. This method allows for simple OLS estimation and, under some conditions, comparative static analysis.

We can simplify the reduced form gravity equation in Baier and Bergstrand (2009) to the case of a cross section of importers to get

$$\ln\left(\frac{X_{ij}}{Y_j}\right) = \alpha + (1-\sigma)\left[\ln T_{ij} - \sum_{k=1}^{N} \theta_k \ln T_{kj}\right], \tag{5}$$

where X_{ij} is export from either the U.S. or Spain to country j, Y_j is income (GDP) of j, T_{ij} are trade costs between the U.S. or Spain and j, α is a constant, σ is the elasticity of substitution between domestic and foreign goods, $\theta_k = \frac{Y_k}{\sum_{l=1}^{N} Y_l}$ is the share of country k in world income and N is the number of countries in the world (also including j). The sum of income-weighted trade costs between j and all the countries (second term in the bracket) captures the MTR of country j. Note that the sum also includes domestic trade costs, i.e. T_{jj}.

This formula captures the intuition behind Anderson's and van Wincoop's (2003) result: trade flows only depend on relative trade costs. If all trade costs (including domestic trade cost) go up by the same amount, then trade does not change, because $\sum_{k=1}^{N} \theta_k = 1$. To conduct comparative statics with respect to an element of trade costs, we need to check how it affects *relative* trade costs.

Here we need to take into account that the administrative barrier (and also some other trade cost) variables do not have a true bilateral variation. Let us define a log-linear trade cost function that contains two types of costs and an additive error term,

$$\ln T_{ij} = \delta_1 t_{ij} + \delta_2 f_{ij} + u_{ij},$$

[13] Most empirical applications use country fixed effects (or country-time fixed effects in panels) to control for the MTRs. In our case fixed effects estimation is not applicable, since we have only a country cross section. A bilateral database would not help either, because we want to identify the effect of a trade cost variable that has no bilateral variation.

where $f_{ij} = f_j$ for all $i \neq j$ and $f_{ij} = 0$ for $i = j$ and the δ's are parameters. It is easy to see that the term in the bracket in equation (5) simplifies to $\theta_j f_j$ for the second type of trade cost. After substituting the trade cost function the gravity equation becomes

$$\ln\left(\frac{X_{ij}}{Y_j}\right) = \alpha + (1-\sigma)\delta_1\left[t_{ij} - \sum_{k=1}^{N}\theta_k t_{kj}\right] + (1-\sigma)\delta_2\theta_j f_j + u_{ij}. \tag{6}$$

In principle, estimating (6) gives consistent estimates of the gravity parameters. In practice, there are two issues to consider. The first is a multicollinearity problem among the right-hand-side variables. Severe multicollinearity can occur either between the importer's GDP (if put on the right-hand side) and $\theta_j f_j$, or among two or more $\theta_j f_j$ terms. The second issue is that the gravity parameter to estimate for the administrative barrier variable will be far larger than the corresponding comparative static effect (Behar, 2009). The gravity parameter is $(1-\sigma)\delta_2$ and the comparative static effect (specific to j) is approximately $(1-\sigma)\delta_2\theta_j$. The difference is a factor of the importer's income share, so it is always large.[14]

We propose a modification of the estimating equation that helps resolve both concerns. We decompose $\theta_j f_j$ in equation (6) as

$$\theta_j f_j = \bar{\theta}\ f_j + (\theta_j - \bar{\theta})f_j, \tag{7}$$

where $\bar{\theta}$ is the mean of the θ_js across all importers. If instead of $\theta_j f_j$ we include f_j and $(\theta_j - \bar{\theta})f_j$ separately in the estimating equation, we can consistently estimate the comparative static effect for the average-sized importer, $(1-\sigma)\delta_2\bar{\theta}$, as the coefficient on f_j, which is not collinear with Y_j.

We apply solution (7) only to the administrative barrier variable and calculate the MTR-adjusted trade costs as in (6) for the other trade cost regressors.[15] Income shares are based on GDP data. The world total is the sum of importers plus U.S. or

[14] The difference can also get non-negligible for trade costs with bilateral variation, if at least one of the trade partners has a relatively large income share. Formally, the comparative static effect for the bilateral trade cost is $(1-\sigma)\,\delta_1\,(1-\theta_j-\theta_i+\theta_i\theta_j)$.

[15] Domestic trade costs, T_{jj}, are internal distance, 1 for the FTA, PTA, colony and language dummies, 0 for landlocked and island and the other Doing Business trade cost variable.

Spain. As before, we include both log GDP and log GDP per capita on the right-hand side.

Table 9: Theory-consistent gravity estimates, Time cost

Dependent variable	β estimate	s.e.	Adj./Pseudo R^2
	Exporter is U.S.		
log total export	-0.006	[0.008]	0.85
log shipment extensive	-0.015*	[0.009]	0.85
log price	-0.001	[0.002]	0.07
log within physical size	0.007**	[0.003]	0.38
log transport mode	0.002	[0.001]	0.32
log product composition	0.002	[0.003]	0.09
Number of observations	170		
Test $\beta_{price}+\beta_{within}=0$	$\chi^2(1)=3.74$, p-val=0.053		
Breusch-Pagan test	$\chi^2(10)=80.57$, p-val=0.000		
	Exporter is Spain		
log total export	-0.027***	[0.008]	0.87
log shipment extensive	-0.033***	[0.009]	0.88
log price	0.003	[0.003]	0.20
log within physical size	0.005	[0.005]	0.24
log transport mode	-0.001	[0.002]	0.08
log product composition	0.000	[0.003]	0.08
Number of observations	143		
Test $\beta_{price}+\beta_{within}=0$	$\chi^2(1)=3.10$, p-val= 0.079		
Breusch-Pagan test	$\chi^2(10)=81.45$, p-val=0.000		

Note: OLS estimation with robust standard errors for total exports, SURE for the margins, on a cross section of importers. Pseudo R^2 is for SURE. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and time to complete port/terminal handling and transport from nearest seaport. MTR is controlled for by the method of Baier and Bergstrand (2009). Breusch-Pagan test is for residual independence in SURE. * significant at 10%, ** 5%; *** 1%.

The results, presented in Tables 9 and 10, reinforce the previous findings. We find strong evidence for a negative response on the shipment extensive margin to administrative barriers. Both U.S. and Spanish exporters send less shipments to destinations with more burdensome documentation and customs procedures. Larger administrative barriers are also associated with larger shipment sizes. In the case of U.S. exports, it is clearly due to larger physical shipment sizes and not higher prices. Finally, we estimate mainly positive coefficients on the transport mode and product composition margins, although these are often qualitatively small and statistically not significant.

Table 10: Theory-consistent gravity estimates, Log monetary cost

Dependent variable	β estimate	s.e.	Adj./Pseudo R^2
	Exporter is U.S.		
log export	-0.148	[0.161]	0.85
log number of shipments	-0.278*	[0.146]	0.85
log price	-0.052	[0.032]	0.08
log physical shipment size	0.109**	[0.048]	0.37
log mode composition	0.008	[0.020]	0.31
log product composition	0.064	[0.048]	0.10
Number of observations	170		
Test $\beta_{price}+\beta_{physicalsize}=0$	$\chi^2(1)=1.57$, p-val=0.211		
Breusch-Pagan test	$\chi^2(10)=77.05$, p-val=0.000		
	Exporter is Spain		
log export	-0.020	[0.171]	0.86
log number of shipments	-0.017	[0.148]	0.86
log price	0.026	[0.045]	0.19
log physical shipment size	0.005	[0.083]	0.23
log mode composition	0.012	[0.028]	0.06
log product composition	-0.046	[0.052]	0.09
Number of observations	143		
Test $\beta_{price}+\beta_{physicalsize}=0$	$\chi^2(1)=0.21$, p-val= 0.648		
Breusch-Pagan test	$\chi^2(10)=82.04$, p-val=0.000		

Note: OLS estimation with robust standard errors for total exports, SURE for the margins, on a cross section of importers. Pseudo R^2 is for SURE. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and cost to complete port/terminal handling and transport from nearest seaport. MTR is controlled for by the method of Baier and Bergstrand (2009). Breusch-Pagan test is for residual independence in SURE. * significant at 10%, ** 5%; *** 1%.

4 A model of the welfare costs of shipping frequency

This section presents a model that determines the number and timing of shipments to be sent to a destination market. Sending shipments more frequently is beneficial, because the specifications of the product can be more in line with the demands of the time. Producers engage in monopolistic competition as consumers value the differentiated products they offer. Each producer can then send multiple shipments to better satisfy the demands of its consumers.

4.1 Consumers

There is a unit mass of consumers in the destination country.[16] Consumers are heterogeneous with respect to their preferred date of consumption: some need the good on January 1, some on January 2, etc. The preferred date is indexed by $t \in [0, 1]$, and can be represented by points on a circle.[17] The distribution of t across consumers is uniform, that is, there are no seasonal effects in demand.

Consumers are willing to consume at a date other than their preferred date, but they incur a cost doing so. In the spirit of the trade literature, we model the cost of substitution with an iceberg transaction cost.[18] A consumer with preferred date t who consumes one unit of the good at date s only enjoys $e^{-\tau|t-s|}$ *effective units*. The parameter $\tau > 0$ captures the taste for timeliness.[19] Consumers are more willing to purchase at dates that are closer to their preferred date and they suffer from early and late purchases symmetrically.

[16] For simplicity, we are omitting the country subscript in notation.

[17] Note that this puts an upper bound of $\frac{1}{2}$ on the distance between the firm and the consumer. We are following the "circular city" discrete choice model of Salop (1979).

[18] This is different from the tradition of address models that feature linear or quadratic costs, but gives more tractable results.

[19] As an alternative, but mathematically identical interpretation, we may say that the consumer has to incur time costs of waiting or consuming too early (e.g., storage) so that the total price paid by her is proportional to $e^{\tau|t-s|}$.

Other than the time cost, consumers value the shipments *from the same producer* as perfect substitutes. The utility of a type-t consumer purchasing from producer ω is

$$X(t,\omega) = \sum_{s\in S(\omega)} e^{-\tau|t-s|}x(t,\omega,s). \tag{8}$$

Clearly, because of perfect substitution, the consumer will only purchase the shipment(s) with the closest shipping dates, as adjusted by price, $e^{-\tau|t-s|}/p_s$.

The consumer then has constant-elasticity-of-substitution (CES) preferences over the bundles $X(t,\omega)$ offered by different firms.[20]

$$U(t) = \int_\omega X(t,\omega)^{1-1/\sigma} d\omega, \tag{9}$$

where σ is the elasticity of substitution. Consumers spend a fixed E amount on imported goods.[21]

4.2 Suppliers

There is an unbounded pool of potential suppliers to the destination country. Every supplier can choose the number and timing of shipments they send. We are interested in a symmetric equilibrium, where all suppliers are identical in their costs and choose identical actions.

Suppliers first decide whether or not to enter a particular destination market. This has a fixed cost f_e, which captures the costs of doing business in the country and setting up a distribution network there. They then decide how many shipments to send at what times. Sending a shipment incurs a per-shipment cost of f. Finally, they decide how to price their product. All these decisions are done simultaneously by the firms.

The marginal cost of selling one unit of the good is constant at c. This involves the costs of production, but also the per-unit costs of shipping, such as freight charges

[20]We model the substitution across firms separately from the substitution across shipments for analytical tractability. This way, the traditional competition effects are almost independent from the choice of shipping frequency.

[21]It is straightforward to endogenize E in a Krugman-type model. Because we are focusing on the new margin, we are expressing the welfare effects for given total export.

and insurance. (It does not include per-shipment costs.) We abstract from capacity constraints in shipping, that is, any amount can be shipped to the country at this marginal costs.[22]

Given this cost structure, we can write the profit function of producers as

$$\pi(\omega) = [p(\omega) - c] \int_t \sum_{s=s_1,\ldots,s_{n(\omega)}} x(t,\omega,s)dt - n(\omega)f - f_e. \tag{10}$$

Net revenue is markup times the quantity sold to all different types of consumers at different shipping dates. We have already anticipated that each consumer faces the same price, which is something we prove below. The per-shipment costs have to be incurred based on the number of shipping dates.[23] We also subtract the market entry cost.

4.3 Equilibrium

We focus on symmetric equilibria. A *symmetric equilibrium* of this economy is a product price p, a measure of firms serving the market M, the number of shipments per firm n, and quantity $x(s,t)$ such that (i) consumer demand maximizes utility, (ii) prices maximize firm profits given other firms' prices, (iii) shipping frequency maximizes firm profits conditional on the shipping choices of other firms, (iv) firms make zero profit, and (v) goods markets clear.

To construct the equilibrium, we move backwards. We first solve the pricing decision of the firm at given shipping dates. We then show that shipments are going to be equally spaced throughout the year. Given the revenues the firm is collecting from n equally spaced and optimally priced shipments, we can solve for the optimal number of shipments. Finally, we can determine the number of exporting firms from the free entry condition.

[22]This is not going to be a concern in the symmetric equilibrium of the model. Larger, more attractive countries will be served by many firms, so none of them would like to send oversized shipments.

[23]Clearly, the firm would not send two shipments on the same date, as it would only reach the same type of consumers. More on the equilibrium shipping dates below.

Pricing. The demand (in terms of revenue) for the product of firm ω shipped at time s, coming from consumer t is

$$R(t,\omega,s) = E(t)\left[\frac{p(\omega)e^{\tau|s-t|}}{P(t)}\right]^{1-\sigma}, \tag{11}$$

where $E(t)$ is the expenditure of consumer t, $p(\omega)$ is the price of the product, and

$$P(t) = \left[\int_{\omega} p(\omega)^{1-\sigma} e^{-(\sigma-1)\tau|t-s(\omega)|} d\omega\right]^{1/(1-\sigma)}$$

is the ideal price index of consumer t. Because there is a continuum of competitors, an individual firm does not affect the price index $P(t)$ nor expenditure $E(t)$. This implies that the firm's demand is isoelastic with elasticity σ. As a consequence, the firm will follow the inverse elasticity rule in its optimal pricing,

$$p(\omega) = \frac{\sigma}{\sigma-1}c. \tag{12}$$

Price is a constant markup over the constant marginal cost. Because all firms charge the same price to all consumers, we drop the ω in the notation below.

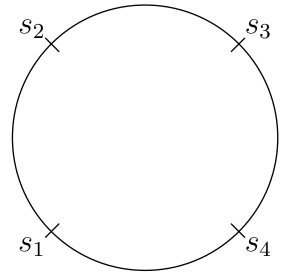
Shipping dates. Clearly, revenue (11) is concave in $|s-t|$, the deviation of shipping times from optimal. Because of that, the firm would like to keep shipments equally distant from all consumers. This implies that shipments will be equally spaced, $s_2 - s_1 = s_3 - s_2 = ... = 1/n$. The date of the first shipment is indeterminate, and we assume that firms randomize across all possible dates uniformly.

Because all shipments have the same price, consumers will pick the one closest to their preferred date t. (Other shipments are strictly inferior.) The set of consumers purchasing from a particular shipment s is $t \in [s - \frac{1}{2n}, s + \frac{1}{2n})$.

An equal-spaced shipping equilibrium is shown on Figure 1.

Net revenue. The firm will care about the net revenue coming from its sales. Because markup is constant, net revenue is just a constant $1/\sigma$ fraction of gross revenue.

Figure 1: Symmetric equilibrium shipping dates



To obtain gross revenue from a shipment s, we integrate across the set of buyers buying from that shipment,

$$R(s) = \int_{t=s-\frac{1}{2n}}^{s+\frac{1}{2n}} E(t) \left[\frac{p}{P(t)}\right]^{1-\sigma} e^{-(\sigma-1)\tau|s-t|} dt = E\left(\frac{p}{P}\right)^{1-\sigma} \int_{t=s-\frac{1}{2n}}^{s+\frac{1}{2n}} e^{-(\sigma-1)\tau|s-t|} dt,$$

where we have exploited the symmetry of consumers and firms. The integral in the last term evaluates to

$$\int_{t=s-\frac{1}{2n}}^{s+\frac{1}{2n}} e^{-(\sigma-1)\tau|s-t|} dt = 2 \cdot \frac{1-e^{-\frac{1}{2}(\sigma-1)\tau/n}}{(\sigma-1)\tau}.$$

To economize on notation later, we introduce the term

$$\chi \equiv (\sigma-1)\frac{\tau}{2n} \tag{13}$$

and write the integral as

$$\int_{t=s-\frac{1}{2n}}^{s+\frac{1}{2n}} e^{-(\sigma-1)\tau|s-t|} dt = \frac{1}{n}\frac{1-e^{-\chi}}{\chi}.$$

The revenue from all shipments is then

$$R = \sum_s R(s) = nR(s) = E\left(\frac{p}{P}\right)^{1-\sigma} \frac{1-e^{-\chi}}{\chi}. \tag{14}$$

This is increasing in n: the more shipments the firm sends the more consumers it can reach at a low utility cost. Because they appreciate the close shipping dates, they will demand more from this firm relative to other firms. At the extreme, if $n \to \infty$, the last term converges to 1, and the firm sells $Ep^{1-\sigma}P^{\sigma-1}$.

Number of shipments. Choosing the profit-maximizing number of shipments involves maximizing

$$\max \frac{R}{\sigma} - nf$$

with respect to n. Net revenue is R/σ and each shipment incurs the per-shipment cost f. Revenue R only depends on the number of shipments through χ. The first-order condition for the optimum is

$$\frac{dR/\sigma}{dn} = \frac{R}{\sigma n} \frac{1 - (1+\chi)e^{-\chi}}{1 - e^{-\chi}} = f. \tag{15}$$

As χ depends on n, this equation defines the optimal number of shipments implicitly. We later characterize n when we conduct comparative statics across equilibria.

Free entry. Free entry ensures that firms make zero profit,

$$\frac{R}{\sigma} - nf - f_e = 0.$$

In symmetric equilibrium, R is equally divided among firms,

$$R = \frac{E}{M},$$

where $E = \int_{t=0}^{1} E(t)dt$ is the overall import expenditure of the country and M is the measure of firms exporting there. Combining the two equations,

$$\frac{E}{M} = \sigma(f_e + nf). \tag{16}$$

The following proposition characterizes the equilibrium.

Proposition 1. *A symmetric equilibrium exists and is unique up to a rotation of shipping dates along the circle. The equilibrium price is*

$$p^* = \frac{\sigma}{\sigma - 1} c,$$

the equilibrium number of shipments n^* is implicitly determined by

$$\frac{\chi^*}{e^{\chi^*} - 1} = \frac{f_e}{f_e + n^* f}, \tag{17}$$

where $\chi^* = \frac{1}{2}(\sigma - 1)\tau/n^*$, and the equilbrium quantity is

$$x^*(s,t) = \frac{(\sigma-1)f_e}{c} e^{(1-\sigma)\tau\left[|s-t| - \frac{1}{2n^*}\right]}. \tag{18}$$

Proof. The pricing rule has been derived before, so we complete the proof by showing that equations (17) and (18) satisfy the equilibrium conditions, and that (17) has a unique solution. The unicity of (18) for a given n^* is trivial.

Equation (17) follows from combining the first-order condition for profit-maximizing n (15) with the free entry condition (16). Note that χ is decreasing in n by the definition (13), so the left-hand side is increasing in n^*. The right-hand side, in turn, is decreasing in n^*. This ensures uniqueness. When $n = 0$, we have $\chi = \infty$, and the LHS is zero, while the RHS is one. When $n = \infty$, $\chi = 0$ and the LHS is one, whereas the RHS is zero. This ensures existence.

Equation (18) follows from (11), making use of the pricing rule and integrating over all shipments to obtain the price index as

$$P = pe^{\frac{1}{2}\tau/n} \left(\frac{\sigma f_e}{E}\right)^{1/(\sigma-1)}.$$

□

Proposition 1 yields interesting comparative statics for the equilibrium shipping frequency n^*. Most importantly, it is decreasing in per-shipment costs f and increasing in the importance of timely delivery τ.

5 Welfare

What is the welfare cost of administrative barriers? Here we calculate how welfare depends on the choice of shipping frequency. The utility of the representative consumer is a monotonic function of real income E/P. We hence need to calculate the price index faced by the representative consumer. Using the definition of the price index, the fact that firms are symmetric, and the free entry condition pinning down the mass of firms,

$$P = pe^{\frac{1}{2}\tau/n} \left(\frac{\sigma f_e}{E}\right)^{1/(\sigma-1)}.$$

The price index is increasing in prices. It is also increasing in τ, the utility cost of waiting and decreasing in n. When there are many shipments, the consumer will perceive them as a cheaper way to achieve the same level of utility. The price index also decreases in the size of the market E because of the usual love-of-variety effects: a large market can sustain many producers and many valuable varieties.

Substituting into the formula for utility, we get the following result.

Proposition 2. *The utility of the representative consumer is given by*

$$U = \frac{E}{P} = E^{\sigma/(\sigma-1)} \frac{\sigma - 1}{\sigma c} \exp\left(-\frac{\tau}{2n}\right). \tag{19}$$

It is increasing in the number of shipments n.

At the extreme, when $n \to \infty$, waiting costs vanish and welfare is the same as under the Krugman model. We introduce the following notation for the additional "welfare bias" coming from administrative trade barriers:

$$B = e^{\frac{1}{2}\tau/n}. \tag{20}$$

This is the gap between welfare in our model and welfare in the the Krugman model and will be our key object of interest throughout the calibration. More specifically, a consumer would be willing to spend $B - 1$ fraction of imports in order to get rid of per-shipment costs.

Note that our notion of welfare costs only includes the consumer, and does not account for the profit losses of the producer. The reason is that profits are zero in equilibrium so, ex ante, firms are indifferent with respect to per-shipment trade costs.

5.1 Calibration

We are interested in a quantitative evaluation of the welfare losses from per-shipment costs. We conduct a simple calibration exercise.

They key parameters of the model are σ, the elasticity of substitution, τ, the preference for timely shipments, per-shipment costs f and entry costs f_e. Our strategy is to measure fixed costs directly, and calibrate σ and τ to the observed sensitivity of trade flows to ad valorem, and per-shipment costs, respectively.

Following Eaton and Kortum (2002), we calibrate $\sigma = 8.2$. This means that a 1 percent increase in ad-valorem trade costs reduces trade by $\sigma - 1 = 7.2$ percent. It also implies a 14 percent markup. We also report results with the estimates of Simonovska and Waugh (2010), $\sigma = 4.5$.

We capture administrative trade barriers in the importing country with indicators on the burden of import documentation and customs clearance and inspection. We convert monetary costs to ad-valorem costs by multiplying them with the number of shipments and dividing by the total value. We can also add the ad-valorem equivalent of time costs, taking the semi-elasticity of the traded value to time costs (-0.006) from the first row of Table 9. Then, in terms of traded value a day is worth 0.08% under $\sigma = 8.2$ and 0.17% under $\sigma = 4.5$.[24]

The remaining key parameter is τ. We calibrate it using the following strategy. We can infer the preference for timely shipments from the demand for shipments. In the model, the elasticity of the number of shipments with respect to per-shipment costs is

$$\varepsilon(n, f) \equiv \frac{d \ln n}{d \ln f} = -\frac{d \ln \chi}{d \ln f} = \frac{1}{e^{\chi} - 1} - \frac{1}{\chi}. \tag{21}$$

However, χ is not directly observed because we do not measure shipments by firm n in the data, only the total number of shipments $N = nM$. In the calibration exercise, we want to express the welfare measure as a function of observables. This is given by the following proposition.

Proposition 3. *The log welfare gap is given by*

$$\ln B = \frac{1}{2} \frac{\sigma}{\sigma - 1} \frac{Nf}{E} \frac{1}{|\varepsilon(n, f)|}. \tag{22}$$

Welfare costs are high when per-shipment costs are high in ad-valorem terms (Nf/E) and when the elasticity of shipments to per-shipment costs is low.

Proof. The formula follows from straightforward substitutions of (21) into (20) and

$$\chi = (\sigma - 1)\frac{\tau}{2N} M = (\sigma - 1)\frac{\tau}{2N} \frac{E}{\sigma(f_e + nf)} = \frac{\sigma - 1}{\sigma} \frac{E}{N} \frac{\tau}{f_e + nf}.$$

[24] It is a rather conservative estimate. Hummels and Schaur (2012) estimates the cost of time to be at least 0.6% per day, which yields considerably larger welfare effects.

□

The intuition behind this result is as follows. Welfare costs of per-shipment costs naturally depend on their magnitude Nf/E. The sensitivity of welfare with respect to per-shipment costs is the inverse of the elasticity of the number of shipments with respect to such costs. When timely delivery is very important (τ is high), consumers will demand many shipments, and shipping frequency will not be very sensitive to shipping costs. This is when shipping costs have the biggest welfare bias. By contrast, if people do not value timeliness much (τ is low), shipping frequency will be very sensitive to costs, as that part of the trade-off becomes more important. Welfare costs of per-shipment costs are low in this case.[25]

This way, we can express welfare costs as a function of the elasticity $\varepsilon(n, f)$ directly, without the need to calibrate τ. We have estimated this elasticity to be -0.278 in Table 10.

5.2 Results

To express the welfare cost as a fraction of GDP, we multiply $\ln B$ by the import penetration of the country E/Y, where E is total imports of goods. Such a welfare measure is more comparable to existing measures of gains from trade as it answers the question "what fraction of consumption the consumers would give up in exchange for getting rid of administrative trade barriers."

Table 11 shows the median ad-valorem trade costs for the 170 countries in the U.S. sample. It also displays the median welfare loss from per-shipment costs for different σ parameter values. Monetary costs are, for the median country, 1 percent of shipment value. This corresponds to a welfare loss from infrequent shipments of slightly less than 1 percent of GDP. When we add the time costs of trade, the welfare losses become 2–3 percent of GDP.

We also ask how welfare would change in each country if they adopted the import procedures of the U.S. A typical U.S. import shipment waits only 3 days for customs clearance and documentation, and this procedure costs $295.

[25]Note that a similar formula applies to the formula for the welfare cost of *ad valorem* trade costs, equation (1) of Arkolakis et al (2012). The intuition there is also similar.

Table 11: Calibration results

	$\sigma = 8.2$	$\sigma = 4.5$
Monetary costs	1.0%	
Time costs	1.3%	2.6%
Total costs	2.3%	3.6%
Welfare loss (% of GDP)		
from monetary costs	0.8%	0.9%
from time costs	0.9%	2.1%
total	1.9%	3.3%

Figure 2: Welfare gains from adopting U.S. administrative barriers: The role of trade barriers

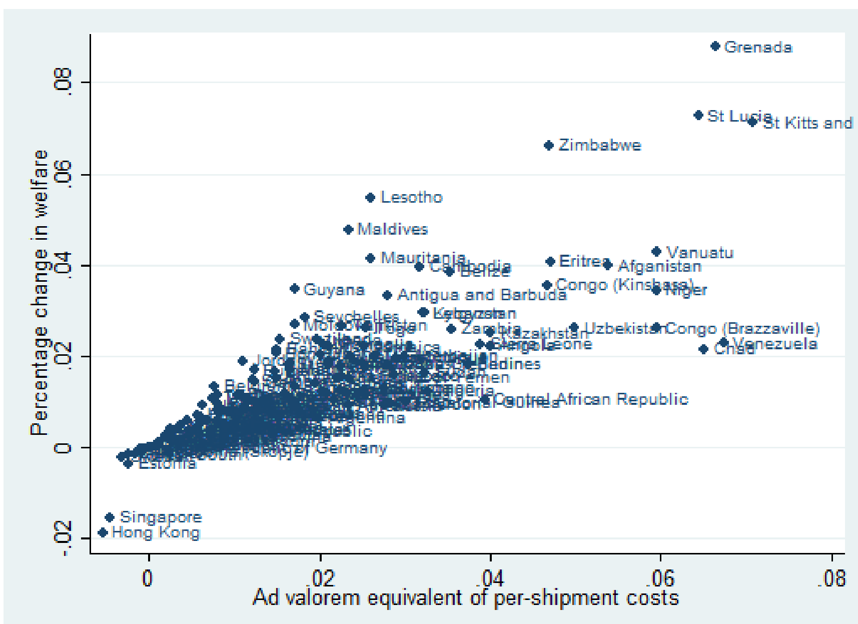


Figure 2 reports the welfare change (in percentage of the country's GDP) plotted against the ad-valorem equivalent of per-shipment costs (both monetary and time). The figure is constructed for $\sigma = 8.2$.

There are several European economies, South Korea and the entrepot economies of Singapore and Hong Kong that would actually lose from adopting the U.S. standards. These countries have even lower administrative barriers and trade in large volumes. However, for the majority of countries, the welfare gains are positive (1.4 percent of GDP, on average).

Not surprisingly, potential welfare gains are increasing in the magnitude of administrative costs. These are costs that would be replaced under the counterfactual policy. For some countries the gains can be as large as 5–8 percent of GDP.

Figure 3: Welfare gains from adopting U.S. administrative barriers: The role of import penetration

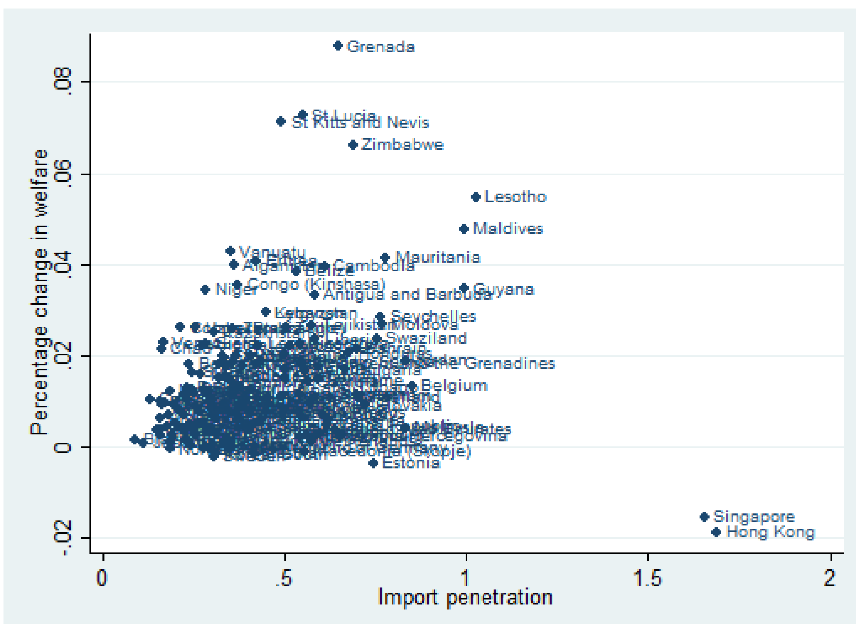


Figure 3 reports the same welfare gain as a function of the import penetration of the country. Mechanically, countries with a high share of import would gain more, because they can enjoy the benefits of lower trade barriers on a larger amount. However, this pattern is not clear: countries with the largest import penetration, such as Hong Kong and Singapore actually lose via the policy changes. Such highly open countries tend to already have very low administrative barriers.

6 Conclusion

Administrative barriers to trade such as document preparation and the customs process are non-negligible costs to the trading firm. Since such costs typically arise after each shipment, the firm can economize on them by sending fewer but larger shipments to destinations with high administrative costs. Such a firm response can partly explain the lumpiness of trade transactions, which has recently been documented in the literature. Exploiting the substantial variation in administrative trade barriers by destination country, this paper provided empirical evidence on disaggregated US and Spanish export data that firms send larger-sized shipments less frequently to high-cost destinations.

Less frequent shipments cause welfare losses because of the larger discrepancy between the actual and the desired time of consumption. We built a model to analyze the welfare effects of per-shipment administrative trade costs. Having calibrated the model to observed shipping frequencies and per-shipment costs, we showed that countries would gain substantially by eliminating such barriers. This suggests that trade volumes alone are insufficient to understand the gains from trade.

More broadly, we believe that there are significant gains from trade beyond those captured in the canonical models surveyed in Arkolakis et al. (2012). There are other margins through which trade liberalization affects domestic welfare, be it flexibility, timeliness or externalities stemming from foreign knowledge. Our view is supported by reduced-form evidence provided by Feyrer (2009a,b), who exploits plausibly exogenous variation in geography to estimate gains from trade that are an order of magnitude larger than previous model-based estimates.

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A Data reference

US export data. US exports data is from the foreign trade database of the U.S. Census Bureau. We consider only exports in 2005 to 170 destination countries. Monthly trade flows are recorded in 10-digit HS (Harmonized System) product, destination country and U.S. district of origin dimensions. Although it is not a shipment-level database, more than half of the observations represent only one shipment.[26] Information is available on the number of shipments, the value in U.S. dollars and the quantity of trade, as well as the value and weight of trade transported by air or vessel.

If the value of trade by air or vessel does not cover total trade value, we assume ground transportation. We drop those observations, where trade is associated with more than one transport mode (5.8% of observations, 25% of total number of shipments). Hence, one of the three transport modes (air, vessel, ground) is uniquely assigned to each observation.

We drop product lines, which correspond to low-value shipments. In the Census database trade transactions are reported only above a trade value threshold (USD 2,500 for exports). Low value shipment lines are estimates based on historical ratios of low value trade, except for Canada, where true data is available. They are classified under two product codes as aggregates. Hence, they appear erroneously as two large shipments and distort the shipment size distribution.[27]

We also drop product lines that mainly cover raw materials and fuels according to the BEC (Broad Economic Categories) classification. These are the products under

[26] The U.S. Census Bureau defines a shipment accordingly: "Unless as otherwise provided, all goods being sent from one USPPI to one consignee to a single country of destination on a single conveyance and on the same day and the value of the goods is over $2,500 per schedule B or when a license is required.", where USPPI is a U.S. Principal Party in Interest, i.e. "The person or legal entity in the United States that receives the primary benefit, monetary or otherwise, from the export transaction."

[27] Low value shipment lines are 9880002000: "Canadian low value shipments and shipments not identified by kind", 9880004000: "Low value estimate, excluding Canada". In addition, we also drop the product line 9809005000: "Shipments valued USD 20,000 and under, not identified by kind".

the BEC codes 111-112 (primary food and beverages), 21 (primary industrial supplies), 31 (primary fuels and lubricants) and 321-322 (processed fuels and lubricants).

In the database there is no single quantity measure, which would apply to all product categories: product quantities are measured either in kilograms, numbers, square meters, liters, dozens, barrels, etc. In addition, weight in kilograms is recorded as separate variables for trade shipped by air or vessel.

We calculate price as a unit value, i.e. value over quantity. It is an f.o.b. price, since exports are valued at the port of export in the U.S. and include only inland freight charges. It is important to calculate the price at least at the 10-digit product level, where the quantity measure per product is unique. For some products the quantity measure is not defined; here we assume that quantity equals value, i.e. the quantity measure is a unit of U.S. dollar.

Spanish export data. Data on Spanish exports in 2005 is from the Spanish Tax Authority (Agencia Tributaria). It is a universal shipment-level database that records, among others, the month, the 8-digit CN (Combined Nomenclature) product code, the destination country, the transport mode, the value in euros and the weight in kilograms for each transaction.

In 2005 Spain exported only to 166 out of the 170 destination countries we consider for the US. In the regression analysis, we drop exports within the EU and, hence, the number of destination countries fall to 143. (Malta is not among the 166.)

This database includes low-value transactions. To make it comparable to the U.S. database we drop transactions of value below EUR 2,000 (USD 2,500 converted to euros with the annual average exchange rate in 2005). Similar to the U.S. case, we also drop transactions in raw materials and fuels. When necessary, we convert data in euros to U.S. dollars with monthly average exchange rates.

Other data. GDP and GDP per capita of the importer countries in current USD for year 2005 is from the World Bank's World Development Indicators database. Total imports of goods in current USD in 2005 is from the World Trade Organization's Statistics Database.

Gravity variables (bilateral geographical distance, internal distance, dummies for landlocked, common language, colonial ties) are from CEPII. Bilateral distance is the population-weighted average of bilateral distances between the largest cities in the two countries, common language dummy refers to official language, colonial ties dummy refers to colonial relationship after 1945.[28]

The FTA and PTA dummies indicate free trade agreements and preferential trade agreements, respectively, effective in year 2005. They are based on the Database on Economic Integration Agreements provided by Jeffrey Bergstrand on his home page.[29] We define PTA as categories 1-2, FTA as categories 3-6 in the original database.

[28]Description of variables by CEPII: http://www.cepii.fr/distance/noticedist_en.pdf

[29]http://www.nd.edu/~jbergstr/#Links

B Tables

Table B.1: Shipment size by mode of transport

Transport mode	Value shipment size (US$) mean	median	st.dev	Physical shipment size (kg) mean	median	st.dev
	Exporter is US					
air	37169	12757	249284	318	72	1264
sea	62102	21424	364305	51156	5368	838271
ground	28838	14273	681885	13870	7131	45985
all	35193	15200	460577	15188	964	389427
	Exporter is Spain					
air	28833	6570	408154	468	92	10325
sea	57418	14808	946887	42081	5350	522298
ground	69472	11947	566320	21781	1540	396921
all	61325	11842	686071	25248	1512	416202

Note: U.S. exports to 170 importers (most detailed data) and Spanish exports to 166 importers (shipment-level data) in 2005. In the case of U.S. exports, statistics are frequency-weighted and physical shipment size is taken only when quantity is reported in kilograms.

Table B.2: Importer countries in the regressions

US	Spain	importer
1	1	Afghanistan
2	2	Albania
3	3	Algeria
4	4	Angola
5	5	Antigua and Barbuda
6	6	Argentina
7	7	Armenia
8	8	Australia
9		Austria
10	9	Azerbaijan
11	10	Bahamas
12	11	Bahrain
13	12	Bangladesh
14	13	Belarus
15		Belgium
16	14	Belize
17	15	Benin
18		Bhutan
19	16	Bolivia
20	17	Bosnia-Herzegovina
21	18	Botswana
22	19	Brazil
23	20	Brunei
24	21	Bulgaria
25	22	Burkina
26	23	Burundi
27	24	Cambodia
28	25	Cameroon
29	26	Canada
30	27	Cape Verde
31	28	Central African Rep.
32	29	Chad
33	30	Chile
34	31	China
35	32	Colombia
36	33	Comoros
37	34	Congo (Brazzaville)
38		Congo (Kinshasa)
39	35	Costa Rica
40	36	Croatia
41		Cyprus
42		Czech Republic
43		Denmark
44	37	Djibouti
45	38	Dominica
46	39	Dominican Republic
47	40	Ecuador
48	41	Egypt
49	42	El Salvador
50	43	Equatorial Guinea
51	44	Eritrea
52		Estonia
53	45	Ethiopia
54		Germany
55	46	Fiji
56		Finland
57		France

U.S.	Spain	importer
58	47	Gabon
59	48	Gambia
60	49	Georgia
61	50	Ghana
62		Greece
63	51	Grenada
64	52	Guatemala
65	53	Guinea
66	54	Guinea-Bissau
67	55	Guyana
68	56	Haiti
69	57	Honduras
70	58	Hong Kong
71		Hungary
72	59	Iceland
73	60	India
74	61	Indonesia
75	62	Iran
76		Ireland
77	63	Israel
78		Italy
79	64	Ivory Coast
80	65	Jamaica
81	66	Japan
82	67	Jordan
83	68	Kazakhstan
84	69	Kenya
85	70	Korea, South
86	71	Kuwait
87	72	Kyrgyzstan
88	73	Laos
89		Latvia
90	74	Lebanon
91		Lesotho
92	75	Liberia
93		Lithuania
94		Luxembourg
95	76	Macedonia (Skopje)
96	77	Madagascar
97	78	Malawi
98	79	Malaysia
99	80	Maldives
100	81	Mali
101	82	Mauritania
102	83	Mauritius
103	84	Mexico
104	85	Moldova
105	86	Mongolia
106	87	Morocco
107	88	Mozambique
108	89	Namibia
109	90	Nepal
110		Netherlands
111	91	New Zealand
112	92	Nicaragua
113	93	Niger
114	94	Nigeria

U.S.	Spain	importer
115	95	Norway
116	96	Oman
117	97	Pakistan
118	98	Panama
119	99	Papua New Guinea
120	100	Paraguay
121	101	Peru
122	102	Philippines
123		Poland
124		Portugal
125	103	Qatar
126	104	Republic of Yemen
127	105	Romania
128	106	Russia
129	107	Rwanda
130	108	Sao Tome and Principe
131	109	Saudi Arabia
132	110	Senegal
133	111	Seychelles
134	112	Sierra Leone
135	113	Singapore
136		Slovakia
137		Slovenia
138	114	Solomon Islands
139	115	South Africa
140		Spain
141	116	Sri Lanka
142	117	St Kitts and Nevis
143	118	St Lucia
144	119	St.Vincent&Grenadines
145	120	Sudan
146	121	Suriname
147	122	Swaziland
148		Sweden
149	123	Switzerland
150	124	Syria
151	125	Tajikistan
152	126	Tanzania
153	127	Thailand
154	128	Togo
155		Tonga
156	129	Trinidad and Tobago
157	130	Tunisia
158	131	Turkey
159	132	Uganda
160	133	Ukraine
161	134	United Arab Emirates
	135	USA
162		United Kingdom
163	136	Uruguay
164	137	Uzbekistan
165	138	Vanuatu
166	139	Venezuela
167	140	Vietnam
168	141	Western Samoa
169	142	Zambia
170	143	Zimbabwe