Exporting Costs and Multi-product Shipments

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Abstract

In this paper, employing transaction level data for Russian imports, we explore the role of multi-product shipments in explaining shipping patterns across countries. First, we document that firms from more developed countries include on average more different products into a single shipment. We then show that such multi-product shipments can potentially explain why more developed countries tend to have a higher number of shipments per period with a lower average quantity and value. The mechanism considered in the paper is based on that multi-product shipments allow splitting fixed costs per shipment across many products and, therefore, reducing total shipment costs. As a result, more developed countries tend to have lower fixed costs per shipment. Finally, we construct a simple partial equilibrium model that enables us to quantify the role of multi-product shipments in determining shipping costs.

Keywords: asymmetric trade costs, fixed costs per shipment, advanced countries.

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1 Introduction

Recent studies argue that countries with different levels of development face different trade costs. For instance, Waugh (2010) and Tarasov (2012) find that less-developed countries countries tend to have higher variable and fixed costs of exporting. Blum, Claro, Dasgupta, and Horstmann (2019) consider a model of trade in the presence of inventory management and show that less developed countries have higher fixed costs per shipment and, as a result, lower aggregate trade volumes. Since the elimination or reduction of these asymmetries boosts exports of less-developed countries and, thereby, increases their income, it is important to understand deeper the micro-foundations behind these differences in export costs.

In this paper, employing transaction level data collected by the Federal Customs Service of Russian Federation, we document a number of empirical observations related to product shipments from many different countries to Russia. In particular, the data allow us exploring the role of multi-product shipments - when different products/varieties are combined in a single shipment - in explaining asymmetric exporting costs faced by countries with different levels of development. We find that firms from more developed countries include on average more different product varieties into a single shipment. We then show that a multi-product shipment tends to have on average lower shipping costs per product (included in the shipment): i.e., there is a scale effect. These findings in turn imply that developed countries have an advantage in international shipping caused by their capabilities to make multi-product shipments, which contributes to higher levels of exports of these countries.

In our analysis, we focus on container shipments, which is the most important shipping category in international trade.[1] The dataset includes information on the identifier of an importer (a firm in Russia), product code, sending country, value, weight and quantity of the product, and the identifier of the shipment. There is

[1] Rua (2014) documents that the global share of containers in general cargo (i.e.,excluding oil, fertilizers, ore, and grain) by volume reaches 70% by mid-2000s.

also information on the number of different varieties of products included in a shipment. Our empirical approach is closely related to that in Blum et al. (2019), so we compare the descriptive statistics and some patterns implied by our dataset with those observed in the Chilean data employed by Blum et al. (2019). We find no crucial differences between the characteristics of the datasets. In particular, in both datasets more developed countries tend to have a higher number of shipments per period with a lower average quantity and value, and a higher average per unit price.

We then argue that more developed countries ship more frequently with a lower quantity and value, partly because they can include a higher number of different products into a single shipment. The intuition behind is that multi-product shipments allow splitting fixed costs per shipment across many products and, therefore, reducing the total shipment costs of a product. The positive relationship between country's development level and the average number of products within a shipment can be in turn explained by that advanced countries tend to export on average a higher number of products to different destinations.[2] Specifically, in our data set, Russian importers import on average more products from more developed countries.

To quantify the role of multi-product shipments in determining the shipment costs of a product, following Blum et al. (2019), we develop a simple partial equilibrium model of product shipping where fixed costs of shipping a product depend on the number of products included in the shipment. In our empirical analysis, we find a strong role of multi-product shipments in explaining shipping patterns across countries. Specifically, as in Blum et al. (2019), higher income countries tend to have lower fixed costs of product shipping. However, in our data, it is mostly due to multi-product shipments. In particular, if we assume that the number of products in each shipment is the same across all countries, the relationship between per capita income and fixed costs of shipping disappears.

To our best knowledge, the only paper that discusses the role of multi-product shipments in the context of trade costs is Holmes and Singer (2018). This pa-

[2] See, for instance, Hummels and Klenow (2005).

per focuses on the importing patterns of US retail chains from China and shows that larger firms include a higher number of product varieties into shipping containers, which allows them to achieve a higher utilization of shipping containers and, thereby, to reduce trade costs. The paper employs a model of trade with indivisibilities to quantify these trade costs saving advantages. The present paper complements Holmes and Singer (2018) by studying cross country patterns of shipments rather than focusing on a single source country and a few importing firms in a given industry. While Holmes and Singer (2018) show that large retailers take an advantage of multi-product shipments, we document that the same applies to exporters from more developed countries and relate it to the fixed cost of product shipping.

Our paper is also related to the literature on the role of fixed costs per shipment. Alessandria, Kaboski, and Midrigan (2010) is one of the first papers that documents the importance of fixed costs per shipment and analyzes their implications for import dynamics. Specifically, they provide evidence that these costs amount to 20-percent tariff equivalent costs. Kropf and Saure (2014) develop this idea further and introduce fixed costs per shipment into a heterogeneous firm framework à la Melitz (2003) and calibrate it to transaction level data for Switzerland. Other studies that use transaction level data to explore the role of fixed costs per shipment include Hornok and Koren (2015) and Bekes, Fontagne, Murakozy, and Vicard (2017). None of these papers consider multi-product shipments.

The rest of the paper is organized as follows. Section 2 describes the data set and presents some empirical patterns. In Section 3, we construct and estimate a partial equilibrium model of product shipping. Section 4 concludes.

2 Data and Empirical Patterns

In this section, we describe the dataset we use in the analysis, present some empirical patterns, and compare our findings with those in Blum et al. (2019).

2.1 Data

In our empirical analysis, we use transaction level data for container shipments to Russia collected by the Russian Federal Customs Service. Container shipments is one of the most important shipping category in international trade. According to Rua (2014), the global share of containers in general cargo (i.e., excluding oil, fertilizers, ore, and grain) by volume reaches 70 percent by mid-2000s. Moreover, by considering container shipments, we are likely to exclude small individuals (a category that is excluded in Blum et al. (2019) as well) and trade in bulk goods that are shipped infrequently but in very large quantities.

The sample period is from February to July of 2014. The six-months period is shorter compared, for instance, with the one-year period considered in Blum et al. (2019). However, the sample size is sufficient to meet our objective (as it covers both winter and summer months of the year, there are few concerns related to seasonal patterns). The dataset includes information on the identifier of the importer, product code, sending country, value, weight and quantity of the product. Importantly, there is also an identifier of the shipment. A single shipment may include products with different product codes.

We present the descriptive statistics in Table 1. It is worth noting that there are substantial similarities between our sample and the one used in Blum et al. (2019). In our sample, we have about 20000 importers, 7000 distinct products codes, from 139 countries. All these numbers are only slightly above the values reported in Blum et al. (2019). The size of our sample is also close to that in Blum et al. (2019).

Compared to Blum et al. (2019), we introduce a new variable: the number of combined shipments. By a combined shipment, we mean a shipment that includes multiple different products. This makes our empirical analysis different from that in Blum et al. (2019). In particular, if in our data a shipment includes N different products, we consider this shipment as a single shipment with multiple products, while Blum et al. (2019) in their analysis would count it as N different shipments. This concept of multi-product shipments is also explored by Holmes and Singer (2018), who consider the importing patterns of US retail chains from China. In our dataset, the number of combined shipments is substantially smaller than the number of shipments: 405641 versus 1628951.

Table 1: Summary Statistics: Russian Import Data

Russian imports (RUR)	1.218×10^{13}
Number of importers	19,787
Number of HS ten-digit codes imported	7,060
Number of source countries	139
Number of shipments	1,628,951
Number of combined shipments	405,641
Average shipment value	7,476,543
Median shipment value	129,297.9

Values are reported in Russian rubles (RUR). During the period of study the average exchange rate was about 34 RUR per USD and had relatively stable dyanmics.

In Panel A of Table 2, we present the distribution of imports with respect to firm size. As usual for trade datasets, the distribution is skewed. In particular, in our dataset, the ratio of the mean to the median is 39 (this ratio is 28 in Blum et al. (2019)). In terms of the number of products purchased by importers, the difference between the median (4 products) and top 1 percent (180 products) is also somewhat larger in our sample. In the Chilean data, the corresponding values are 5 and 156, respectively.

We also observe a large variation between the numbers of countries from which firms source. The median firm sources from one country, while the top 1 percent firms source from 11 countries. For instance, the corresponding numbers in the Chilean data are 1 and 21, respectively. In terms of the number of shipments, the differences between our sample and the Chilean data are quite modest. The median firm makes 8 shipments in both datasets and the top 1 percent firms make about 1000 shipments. In the last column of Panel A, we provide data on the number of combined shipments.

Table 2: Distribution of Key Variables: Russian Imports

	Imports RUR (1)	Number of importers (2)	Number of HS10 codes (3)	Number of source countries (4)	Number of shipments (5)	Number of combined shipments (6)
Panel A. Distribution over importers: 19,787 firms						
P25	2.91×10^6	–	1	1	3	1
P50	1.57×10^7	–	4	1	8	4
P75	2.41×10^8	–	12	2	31	13
P90	9.62×10^8	–	36	4	109	40
P95	2.08×10^9	–	66	6	227	78
P99	8.71×10^9	–	180	11	972	265
Mean	6.16×10^8	–	15.05	1.92	82.32	20.50
Panel B. Distribution over HS ten-digit products: 7,060 codes						
P25	6.00×10^6	3	–	2	6	–
P50	1.21×10^8	10	–	5	28	–
P75	9.19×10^8	36	–	11	144	–
P90	3.59×10^9	109	–	19	525	–
P95	7.46×10^9	193.5	–	25	1099	–
P99	2.33×10^{10}	488	–	34	3372	–
Mean	1.73×10^9	42.02	–	7.77	230.73	–
Panel C. Distribution over importer-HS ten-digit product pairs: 296,653 pairs						
P25	2.67×10^4	–	–	1	1	–
P50	2.68×10^5	–	–	1	2	–
P75	2.44×10^6	–	–	1	3	–
P90	2.57×10^7	–	–	2	9	–
P95	1.10×10^8	–	–	2	17	–
P99	7.12×10^8	–	–	3	68	–
Mean	4.11×10^7	–	–	1.15	5.49	–

In Panel B, we present the distribution of imports across HS ten-digit product codes. We again observe that the distribution is skewed. A given product is on average imported by 42 firms from 8 countries. Both figures are rather close to the ones reported in Blum et al. (2019). Finally, in Panel C we provide information on importer-product pairs. As can be seen, most importer-product pairs are sourced from one country. Only top 10 percent of importer-product pairs are sourced from more than one country. This pattern is similar to that described by Blum et al. (2019).

Note that sourcing from different countries for a given importer-product pair is important, as the identifying variation comes from importer-product pairs (see the estimation strategy described in Section 2.2). To this end, Table 3 classifies importer-pairs into groups, depending on the number of countries from which they are sourced, and presents some descriptive information. As mentioned before, almost 90 percent of importer-product pairs are sourced from one country, which is higher than the corresponding number in Blum et al. (2019). This can be partly due to the fact that we use more detail product codes. Nevertheless, single destination cases account only for 55 percent of imports by volume, which means that almost half of Russian importer-product pairs (measured by volume) are sourced from at least two countries. In our sample, an importer-product pair is imported at most from 15 countries.

To measure the concentration of importer-pairs across countries, in column 5 we report the Herfndahl-Hirschman Index (HHI). For importer-pairs sourced from up to 4 countries, our values are very close to the ones reported by Blum et al. (2019). We also can observe that the index decreases, as the number of countries increases. The only exception is the last line in Table 3 but this is likely due to the fact that we have few observations in that category. In the last column, we present the average absolute deviation of GDP per capita of countries from which an importer-product pair is imported.

Table 3: Characteristics of Importer-HS Ten-Digit Product Pairs

Number of source countries (1)	Number of importer-HS8 pairs (2)	Share of importer-HS8 pairs (3)	Share of imports (4)	HHI imports across countries (5)	Mean absolute deviation country per capita income (6)
1	263450	0.888	0.554	1	0
2	25142	0.085	0.195	0.724	9,304
3	5424	0.018	0.118	0.618	11,896
4	1672	0.006	0.061	0.56	13,256
5	544	0.002	0.026	0.525	13,670
6-10	411	0.001	0.045	0.498	14,758
11-15	10	0.000	0.002	0.539	11,456

Notes: Column 6 reports the mean absolute deviation from the mean per capita income of the countries the importer buys the product from.

2.2 Shipping Patterns across Countries

To exploit the information contained in the transaction level data, we adopt the decomposition approach used in Blum et al. (2019). Specifically, total imports V_{ihl} of product h in HS 10 product category by firm l from country i can be written as

$$V_{ihl} = N_{ihl} \times \bar{s}_{ihl} = N_{ihl} \times \hat{p}_{ihl} \times \bar{q}_{ihl}, \tag{1}$$

where N_{ihl} is the total number of shipments, $\bar{s}_{ihl}$ the average value of a shipment, $\bar{q}_{ihl}$ the average quantity of a shipment, and $\hat{p}_{ihl}$ the weighted average per unit price. More specifically, these variables are defined as:

$$\bar{s}_{ihl} = \frac{1}{N_{ihl}} \times \sum_{k=1}^{N_{ihl}} \left(q_{ihl}(k) \times p_{ihl}(k)\right),$$

$$\bar{q}_{ihl} = \frac{\sum_{k=1}^{N_{ihl}} q_{ihl}(k)}{N_{ihl}}, \quad \hat{p}_{ihl} = \frac{\sum_{k=1}^{N_{ihl}} \left(q_{ihl}(k) \times p_{ihl}(k)\right)}{\sum_{k=1}^{N_{ihl}} q_{ihl}(k)}, \tag{2}$$

where k is a shipment index.

The main empirical specification we consider in this section is given by:

$$ln(z_{ihl}) = \delta_{hl} + \beta_1 ln(gdp_i) + \beta_2 ln(pcgdp_i) + \beta_3 ln(dist_i) + \beta_4 contig_i + \epsilon_{ihl}, \quad (3)$$

where gdp_i is the GDP of the exporting country i, $pcgdp_i$ is its per capita GDP, and $dist_i$ is the population weighted distance between exporter i and Russia, $contig_i$ is a dummy whether country i shares a border with Russia.[3] The specification also includes importer times HS 10 digit product codes denoted by δ_{hl}. Country level variables are taken from the update CEPII Gravity database (Head, Mayer, and Ries, 2010).

The results of estimations are presented in Table 4. In columns 1 through 5, we replicate the results in Blum et al. (2019). As can be seen, the Russian data deliver the results that are very close both qualitatively and quantitatively to those derived for the Chilean data. This provides us confidence that the novel features we document below are not driven by special characteristics of the Russian data. Specifically, we find that more developed countries (proxied by GDP per capita) tend to make more frequent shipments, each shipment made by such countries is smaller and the average price is higher.

It is especially important to emphasize the relationships between GDP per capita with the number of shipments and the average quantity. Our estimates are close to the ones obtained by Blum et al. (2019) both in terms of sign and value. For instance, our estimated coefficient representing the relationship between GDP per capita and the number of shipments is 0.068, while in Blum et al. (2019) it is 0.063. For the relationship between GDP per capita and quantity, we have -0.091

[3]Note that Blum et al. (2019) do not include a contiguity dummy in their empirical analysis. However, in case of Russia, this dummy is an important control variable, as, unlike Chile, Russia shares a border with multiple countries, most of which were the part of the Soviet Union and there are still strong cultural, economic and migration ties. Moreover, as has been shown in the gravity literature, contiguity is a strong predictor of trade flows (see, for instance, Silva and Tenreyro, 2006). Finally, our results in Tables 4 and 5 are similar to those in the specification without the contiguity dummy.

versus −0.287 in their study.

Table 4: Country Characteristics and Shipping Patterns

	$ln(V_{ihl})$	$ln(N_{ihl})$	$ln(\bar{s}_{ihl})$	$ln(\bar{q}_{ihl})$	$ln(\hat{p}_{ihl})$	$ln(\bar{n}_{ihl})$
	(1)	(2)	(3)	(4)	(5)	(6)
GDP	0.177***	0.110***	0.066***	0.091***	0.029***	0.028***
	(0.018)	(0.008)	(0.014)	(0.015)	(0.009)	(0.005)
GDP per cap	-0.021	0.068***	-0.089***	-0.091***	0.063***	0.141***
	(0.032)	(0.014)	(0.024)	(0.027)	(0.016)	(0.009)
Distance	0.164**	-0.085***	0.249***	0.174***	-0.025	-0.165***
	(0.069)	(0.031)	(0.053)	(0.059)	(0.036)	(0.020)
Contiguity	0.426***	0.085***	0.341***	0.286***	-0.010	-0.051***
	(0.065)	(0.029)	(0.051)	(0.055)	(0.033)	(0.018)
R^2	0.929	0.860	0.944	0.943	0.938	0.967
N	343239	343420	343239	343402	343226	343420

Notes: OLS regressions of equation 3. All regressions include importer-by-HS 10 - level fixed effects. Robust standard errors are reported in parentheses. * (**) (***) indicates significance at the 10 (5) (1) percent level.

After assuring that the Russian data exhibit patterns that are very similar to those for the Chilean data in Blum et al. (2019), we explore another dimension of our dataset: multi-product shipments; which is not studied in Blum et al. (2019). As discussed before, making shipments firms can combine different varieties of products into a single shipment. In column 6 of Table 4, our dependent variable is the average number of different products/varieties that are included in a combined shipment made by an importer l from country i in HS 10 product category h. We denote this variable by $\bar{n}_{ihl}$:

$$\bar{n}_{ihl} = \frac{1}{N_{ihl}} \times \sum_{k=1}^{N_{ihl}} n_{ihl}(k),$$

where $n_{ihl}(k)$ is the number of products (in HS 10 category) included in shipment k made by importer l from country i in HS 10 product category h.

As can be seen, there is a positive relationship between the level of GDP per capita and the number of different varieties of products included in a single shipment. In other words, more developed countries include on average a higher number of different varieties of products into a combined shipment. Specifically, our estimates imply that one percent increase in GDP per capita is associated with 0.14 percent increase in the number of products included in a shipment, which seems to be a relatively large effect.

To understand more about the role of multi-product shipments, we adjust some variables of interest in Table 4 by the average number of different products. In particular, in the first column of Table 5, the dependent variable is the total number of shipments (made by a given importer from a given country in a product category) divided by the average number of different products that were included within a shipment $N_{ihl}/\bar{n}_{ihl}$.

This measure somewhat tries to construct a *rough* counterfactual showing how many shipments of product h a firm would have made, if it were to make only single-product shipments of this product. Indeed, one can think that firms try to utilize fully the space in a shipping container (see Holmes and Singer, 2018). Consider then a stylized illustrative example, in which firms ship two symmetric products in equal quantities utilizing the whole space in a container. If we "prohibit" firms filling a container with multiple goods, firms will ship twice the amount of each good within a shipment. Since in each shipment there is twice the quantity of each good, firms will need to make twice fewer separate shipments of each good in a given period to satisfy the same demand.

As can be seen from the first column in Table 5, the relationship between GDP per capita and the adjusted number of shipments, $N_{ihl}/\bar{n}_{ihl}$, is negative and statistically significant, while the relationship between GDP per capita and N_{ihl} is positive (see the second column of Table 4). These empirical patterns potentially imply that more developed countries ship more frequently because of the possibility of making multi-product shipments.

We also introduce adjusted measures for shipment values and quantities:

$$\overline{q_{ihl} \times n_{ihl}} = \frac{1}{N_{ihl}} \times \sum_{k=1}^{N_{ihl}} \left(q_{ihl}(k) \times n_{ihl}(k) \right),$$

$$\overline{s_{ihl} \times n_{ihl}} = \frac{1}{N_{ihl}} \times \sum_{k=1}^{N_{ihl}} \left(s_{ihl}(k) \times n_{ihl}(k) \right).$$

The above measures are supposed to capture the "generalized" total quantity and value of a average shipment of product h. In constructing these variables, we to some extent consider a counterfactual, where all the products in multi-product shipment k of product h have the same quantity and value as product h: $q_{ihl}(k)$ and $s_{ihl}(k)$, respectively. In other words, referring to our previous example, we fill a container with product h only. Clearly, quantities and values of different products are not the same within a multi-product shipment, but since we consider the averages, this does not seem to be a problem.

An alternative approach is to take the total quantity or value of all different products within a combined shipment. We do not follow this approach, as it is important to compare our findings with those in Table 4 and, therefore, to include product fixed effects in our empirical analysis, which is not possible in a specification where the dependent variable is the quantity or valued of all goods in a shipment. Moreover, we know that the set of goods exported by countries varies systematically with the level of economic development (see Levchenko, 2007), implying that physical properties and values of exported goods can be systematically related to the level of income. Our approach with product fixed effects helps to resolve this issue.

Columns 2 and 3 in Table 5 report the relationships between the adjusted measures of value and quantity and exporter's characteristics. In particular, as can be seen, the relationships with GDP per capita are no longer negative, if we compare with those in Table 4. Similar to the case with the adjusted number of shipments, these findings mean that the fact that countries with higher GDP per capita make shipments in smaller quantities and values (as shown in Table 4) can be linked to the possibility of multi-product shipments.

In this paper, we explain the above empirical patterns by the ability of firms from advanced countries of making multi-product shipments, which allows them to split the fixed costs per shipment across many products and, therefore, reduce the total shipment costs. In other words, we argue that more developed countries tend to have lower fixed costs per shipment because they have more possibilities of making multi-product shipments.

It is worth noting that, in this paper, we do not provide micro-foundations for the link between country's development level and the number of multi-product shipments established in column 6 of Table 4. A potential explanation is that, advanced countries tend to export on average a higher number of products to different destinations (see Hummels and Klenow, 2005). To examine this idea, we construct a product range measure for each country-importer pair and regress it on country characteristics. Specifically, our product range measure is the log of the number of different HS 10 products shipped by a country-importer pair during the entire period denoted by $ln(Range_{il})$. Our estimation results are given by (the standard errors are in the brackets below):[4]

$$ln(Range_{il}) = \delta_l + \underset{(0.006)}{0.119} ln(gdp_i) + \underset{(0.009)}{0.058} ln(pcgdp_i) - \underset{(0.020)}{0.005} ln(dist_i) + \underset{(0.038)}{0.657} contig_i + \epsilon_{il}.$$

As can be seen, all else equal, Russian importers import on average more products from more developed countries, which in turn can explain why advanced countries include more products in their shipments.

In the next section, we develop a simple structural model of multi-product shipments to understand their quantitative role.

3 A Partial Equilibrium Shipping Model

In this section, we construct a simple partial equilibrium model of product shipping where fixed costs of shipping a product depend on the number of products included in the shipment. In building the model, we follow Blum et al. (2019) and consider a continuous-time, finite-horizon world with uniform determinis-

[4] $R^2 = 0.67$ and $N = 37261$.

Table 5: Country Characteristics and Adjusted Shipping Patterns

	$ln(N_{ihl}/\bar{n}_{ihl})$	$ln(\overline{s_{ihl} \times n_{ihl}})$	$ln(\overline{q_{ihl} \times n_{ihl}})$
	(1)	(2)	(3)
GDP	0.083***	0.084***	0.110***
	(0.008)	(0.014)	(0.015)
GDP per cap	-0.073***	0.048**	0.046*
	(0.015)	(0.024)	(0.027)
Distance	0.080**	0.090*	0.006
	(0.031)	(0.054)	(0.061)
Contiguity	0.136***	0.261***	0.202***
	(0.030)	(0.050)	(0.055)
R^2	0.938	0.922	0.915
N	343420	343239	343402

Notes: OLS regressions of equation 3. All regressions include importer-by-HS 10 - level fixed effects. Robust standard errors are reported in parentheses. * (**) (***) indicates significance at the 10 (5) (1) percent level.

tic over time demand for any product. Specifically, we denote by x_{ijh} demand in country j at any time $t \in [0,1]$ for product h produced in country i.[5]

We assume that country i (or the distributor of its products) holds an inventory for product h in country j of size $m_{ijh}(t)$ at period t. The inventory depreciation rate is δ (same for all countries and products). Hence, the change in the inventory size at time t, if there are no shipments at this period, can be written as follows:

$$\frac{dm_{ijh}(t)}{dt} = -x_{ijh} - \delta m_{ijh}(t), \tag{4}$$

where the first term represents demand at period t, while the second one stands for the inventory depreciation.

A representative producer (we assume that firms within each country are homogeneous) of product h in country i faces the following trade-off when shipping to country j. On the one hand, shipping is costly implying incentives for the pro-

[5]Note that models on inventory management with stochastic demand cannot be usually solved in a closed form (see Alessandria et al., 2010).

ducer to hold a bigger inventory. On the other hand, a bigger inventory leads to greater losses because of depreciation. Note also that uniform deterministic demand implies that the optimal shipping strategy includes shipments of equal size that are made when the size of the inventory goes to zero (see Arrow, Harris, and Marschak, 1951 and Blum et al., 2019). This in turn means that shipments are made at equal intervals. Hence, taking into account the above trade-off, the producer decides on the number of shipments of product h, n_{ijh}, and their size, s_{ijh}.

Consider a certain interval between two shipments, $[t_0, t_1]$. On this interval, the size of the inventory is given by (we solve the differentiation equation in (4)):

$$m_{ijh}(t) = \frac{-x_{ijh}}{\delta} + Ce^{-\delta t},$$

where C is a certain constant. Taking into account that $m_{ijh}(t_0) = s_{ijh}$, $m_{ijh}(t_1) = 0$, and $t_1 - t_0 = 1/n_{ijh}$, we derive that

$$s_{ijh} = \frac{x_{ijh}}{\delta} \left(e^{\delta/n_{ijh}} - 1 \right). \tag{5}$$

The latter equation describes the shipment size of product h given the demand x_{ijh} and the shipment frequency n_{ijh}.

Hence, the representative producer of product h solves the following optimization problem:

$$min_{\{n_{ijh}, s_{ijh}\}} n_{ijh} \left(K_{ijh} + c_{ijh} s_{ijh} \right) \tag{6}$$

subject to (5). In the above, K_{ijh} is the fixed cost of shipping product h from i to j, while c_{ijh} is the cost of each inventory unit that includes variable transportation and production costs (see Blum et al., 2019). In other words, the producer minimizes the total cost of distributing product h in country j by choosing the frequency and size of shipments. The optimal number of shipments then solves

$$\frac{1}{n_{ijh}} e^{\delta/n_{ijh}} + \frac{1}{\delta} \left(1 - e^{\delta/n_{ijh}} \right) = \frac{K_{ijh}}{c_{ijh} x_{ijh}}. \tag{7}$$

It is straightforward to see that a rise in the ratio $K_{ijh}/c_{ijh}x_{ijh}$ reduces the number of shipments of product h. Specifically, a lower fixed cost of shipping or higher demand for the product naturally leads to more frequent shipments.

3.1 Estimation Strategy

In this section, we estimate the fixed costs of shipping taking into account the possibility of multi-product shipments. In doing this, we follow the estimation strategy in Blum et al. (2019), but assume that K_{ijh} can depend on the total number of products included in this shipment.

Note that the total cost of distributing product h in country j given the optimal choice of n_{ijh} can be written as follows:

$$D_{ijh} = n_{ijh}\left(K_{ijh} + c_{ijh}s_{ijh}\right) = c_{ijh}x_{ijh}e^{\delta/n_{ijh}}.$$

The "traditional" part of this cost is represented by $c_{ijh}x_{ijh}$. However, since the product melts due to inventory management, this cost is multiplied by $e^{\delta/n_{ijh}} > 1$. In other words, we have

$$D_{ijh} = c_{ijh}x_{ijh} + \left(e^{\delta/n_{ijh}} - 1\right)c_{ijh}x_{ijh},$$

where the second term is because of inventory depreciation: if $\delta = 0$, the term disappears.

As in Blum et al. (2019), we assume that the representative producer of product h maximizes its profits taking the market aggregates shipping costs as given:

$$max_{p_{ijh}}\left\{p_{ijh}x_{ijh} - D_{ijh}\right\}$$

where p_{ijh} is the price of the product in market j. Note that we do not restrict the producer to be a multi-product firm (we do not model this explicitly, as it is not necessary for our empirical analysis). In this case, we assume away the cannibalization effects that can arise in a framework with multi-product firms (see Eckel and Neary, 2010 and Mayer, Melitz, and Ottaviano, 2014). Assuming isoelastic demand x_{ijh} with the elasticity of substitution σ and taking into account (5) and (7), it is straightforward to derive that the optimal price is given by

$$p_{ijh} = \frac{\sigma}{\sigma - 1} c_{ijh} \frac{e^{\delta / n_{ijh}} - 1}{\delta / n_{ijh}} = \frac{\sigma}{\sigma - 1} c_{ijh} + \frac{\sigma}{\sigma - 1} c_{ijh} \left(\frac{e^{\delta / n_{ijh}} - 1}{\delta / n_{ijh}} - 1 \right). \quad (8)$$

In the above, as was discussed, the second component stands for a rise in the price caused by inventory depreciation. It is equal to zero, if there is no inventory depreciation.

Under an assumption of a perfectly competitive distribution sector in each country (here we again follow Blum et al., 2019), a producer of product h in country i sold in country j eventually receives a FOB price given by

$$\tau_{ijh} p_{ijh}^{FOB} = p_{ijh} - c_{ijh} \left(\frac{e^{\delta / n_{ijh}} - 1}{\delta / n_{ijh}} - 1 \right),$$

where τ_{ijh} is the variable transportation cost of product h from i to j. In other words, the FOB price is equal to p_{ijh} net of the marginal cost associated with inventory management normalized by τ_{ijh}. We have

$$p_{ijh}^{FOB} = \frac{c_{ijh}}{\tau_{ijh}} \left(\frac{1}{\sigma - 1} \frac{e^{\delta / n_{ijh}} - 1}{\delta / n_{ijh}} + 1 \right). \quad (9)$$

The next step in the estimation procedure is to notice that the total value of exports to j of a firm producing product h in i is given by

$$v_{ijh} = \tau_{ijh} p_{ijh}^{FOB} n_{ijh} s_{ijh}. \quad (10)$$

Taking into account (5) and (9), we derive

$$c_{ijh} x_{ijh} = \frac{v_{ijh}}{n_{ijh} \left(\frac{1}{\sigma - 1} \frac{e^{\delta / n_{ijh}} - 1}{\delta / n_{ijh}} + 1 \right) \frac{e^{\delta / n_{ijh}} - 1}{\delta}}.$$

Substituting the latter into (7), we have

$$\frac{\frac{\delta}{n_{ijh}}e^{\delta/n_{ijh}}+1-e^{\delta/n_{ijh}}}{\frac{n_{ijh}}{\delta}\left(\frac{1}{\sigma-1}\frac{e^{\delta/n_{ijh}}-1}{\delta/n_{ijh}}+1\right)\left(e^{\delta/n_{ijh}}-1\right)}=\frac{\delta K_{ijh}}{v_{ijh}}.$$

Then, linearizing the left-hand side of the latter with respect to δ/n_{ijh} around zero (given the number of shipments in the data, δ/n_{ijh} is sufficiently small), we derive

$$ln(v_{ijh}) - 2ln(n_{ijh}) = const + ln(K_{ijh}) - ln(\delta). \tag{11}$$

In the context of the data set we employ, in the above we substitute the importing country index j for an importer (located in Russia) index l. To control for variations in carrying costs in as flexible a way as possible, we follow Blum et al. (2019) and assume that the value of δ can vary across an exporting country (i), a product (h), and an importer (l). In particular, we assume that $ln(\delta_{ihl}) = ln(\delta_{HS2}) + \epsilon_{ihl}$, where δ_{HS2} is an HS two-digit product fixed effect and ϵ_{ihl} is an unobserved export country, HS product (within HS two-digit category), importer effect.

Finally, in the previous section, we discuss the relevance of multi-product shipments for the fixed cost of shipping a product. Taking this into account, we assume that

$$K_{ihl} = \frac{\widetilde{K}_i}{(\bar{n}_{ihl})^{\kappa}},$$

where κ represents the role of the number of products in a multi-product shipment in determining the fixed cost of shipping a product. Specifically, if $\kappa > 0$, a higher number of products implies a lower fixed cost of shipping per product - there is a scale effect. $\widetilde{K}_i$ stands for the potential variation of the fixed cost across exporters. If we assume away the role of multi-product shipments, our specification will coincide with that in Blum et al. (2019) who consider exporter specific fixed costs of shipping.

Note that, in our partial equilibrium model, we do not endogenize the choice of the number of products included in a shipment. We also do not provide micro-foundations for the link between K_{ihl} and $\bar{n}_{ihl}$. One of the explanations for such a relationship can be a well known fact that the cost of handling half-full and full containers does not differ much (see Alessandria et al., 2010), which in turn potentially implies a lower cost per product of handling full containers, if full containers contain more different products. Financing and insurance also involve some costs. A letter of credit is frequently used in international trade to reduce risks related with the failure of delivery. Typically, these costs include a fixed cost component that does not depend on the number of products in a shipment, implying the discussed link between K_{ihl} and $\bar{n}_{ihl}$.

With all the above reasoning, we obtain the following estimating equation:

$$ln(v_{ihl}) - 2ln(n_{ihl}) = ln(\widetilde{K}_i) - \kappa ln(\bar{n}_{ihl}) - ln(\delta_{HS2}) + \epsilon_{ihl}. \tag{12}$$

In the next subsection, we discuss the results and provide some robustness checks.

3.2 Results

We first report the results for the empirical model in (12). The estimate of κ is 1.35 with a high level of significance, implying a strong role of the number of products in determining the fixed costs of shipping a product. At the same time, it is worth mentioning that it is intuitive to expect κ being less than unity, meaning a concave relationship between K_{ihl} and $\bar{n}_{ihl}$. A possible explanation for such a large estimate of κ is that the HS2 level fixed effects are not sufficient to capture shipping patters across different product categories. Indeed, when we include more detailed level fixed effects in (12), the estimate of κ falls. Estimating (12) with HS6 or HS8 level fixed effects delivers the estimates of κ being lower than unity. Specifically, including HS8 level fixed effects results in the estimate of κ being 0.96, which still means the strong role of the number of products included in a shipment. To compare our findings with those in Blum et al. (2019), we continue considering the model with the HS2 level fixed effects as a benchmark.

Next, we consider the estimate of $\widetilde{K}_i$ and its correlation with country characteristics. As was mentioned, the only difference between our empirical model and that in Blum et al. (2019) is the structural relationship between K_{ihl} and $\bar{n}_{ihl}$ we impose. Therefore, we first report the correlations for $\widetilde{K}_i$ estimated when $\kappa = 0$: that is, when there is no link between the fixed costs and the number of products. We denote this estimate by $\widetilde{K}_i^{Blum}$. As can be seen from column 1 in Table 6, there is a negative correlation between country's per capita income and $\widetilde{K}_i^{Blum}$, meaning that higher income countries have lower fixed costs of shipping a product. This is consistent with the results in Blum et al. (2019), however the coefficient is not significant at conventional levels. In column 2 we report the correlations for the benchmark case: that is, "controlling" for the number of products included in a combined shipment. The correlation between $\widetilde{K}_i$ and per capita income appears to be positive rather than negative and statistically significant at a 10-percent level. This implies a potentially strong, important role of multi-product shipments in explaining shipping patterns across countries. In column 3, we use the estimates of $\widetilde{K}_i$ and κ to calculate $K_{ihl} = \widetilde{K}_i / (\bar{n}_{ihl})^{\kappa}$ and then aggregate K_{ihl} at the country level - we denote this new measure by K_i. In other words, we construct some measure of the fixed costs of shipping a product on the country level taking into account the role of multi-product shipments. Non-surprisingly, this measure is negatively correlated with GDP per capita - higher income countries tend to have lower fixed costs of shipping. However, in our data, it is due to multi-product shipments. Finally, the last three columns in Table 6 report the correlations when the contiguity dummy is taken into account. As can be inferred, the results are very similar.

We noted earlier, that estimate of κ are below unity when we include HS6 level or more detailed fixed effects. For this reason, in Table 7 we report the same correlations between the fixed costs and country characteristics obtained from estimating equation 12 with HS8 fixed effects. As can be seen, the results are not much different from those in Table 6. In particular, we observe that $\widetilde{K}_i^{Blum}$ and K_i are negatively correlated with GDP per capita with the latter being significant at a 5-percent level. While when we take into account the presence of multi-product shipments (columns 2 and 5), the estimated coefficients of interest become positive, although they are not significant.

Table 6: Country Characteristics and Shipping Costs

	$ln(\widetilde{K}_i^{Blum})$	$ln(\widetilde{K}_i)$	$ln(K_i)$	$ln(\widetilde{K}_i^{Blum})$	$ln(\widetilde{K}_i)$	$ln(K_i)$
	(1)	(2)	(3)	(4)	(5)	(6)
GDP	-0.085	-0.017	-0.102	-0.085	-0.017	-0.102
	(0.072)	(0.042)	(0.082)	(0.072)	(0.042)	(0.082)
GDP per cap	-0.063	0.110*	-0.157	-0.063	0.111*	-0.155
	(0.101)	(0.060)	(0.115)	(0.102)	(0.060)	(0.116)
Distance	0.292	0.091	0.571**	0.268	0.070	0.509**
	(0.200)	(0.118)	(0.228)	(0.219)	(0.129)	(0.249)
Contiguity				-0.130	-0.111	-0.338
				(0.474)	(0.280)	(0.540)
R-Adj.	0.055	0.032	0.125	0.056	0.033	0.128
N	127	127	127	127	127	127

Notes: OLS regressions of equation 12. Standard errors are reported in parentheses. * (**) (***) indicates significance at the 10 (5) (1) percent level.

4 Concluding Remarks

In this paper, we explore a potential source of cross-country differences in fixed costs of product shipping that are in turn an important ingredient of cross-country differences in trade patterns. In particular, we relate the fixed costs to the number of products included in a single shipment: in other words, we take into account multi-product shipments. We show that firms from more developed countries tend to include more different products into a single shipment. We then estimate a simple partial equilibrium model of product shipping imposing a structural relationship between the fixed costs of shipping a single product and the number of other products in this shipment. We find that more developed countries tend to have lower fixed costs of product shipping. In our data, it is mostly due to multi-product shipments, which suggests an important role of multi-product shipments in explaining shipping patterns across countries. A fruitful extension of this paper could be a general equilibrium model of trade where the link between fixed costs of shipping and the number of products in a shipment is endogenous. This could shed some more light on the structure of shipping costs and lead to counterfactual

Table 7: Country Characteristics and Shipping Costs (with HS8 FE)

	$ln(\widetilde{K}_i^{Blum})$	$ln(\widetilde{K}_i)$	$ln(K_i)$	$ln(\widetilde{K}_i^{Blum})$	$ln(\widetilde{K}_i)$	$ln(K_i)$
	(1)	(2)	(3)	(4)	(5)	(6)
GDP	0.005	0.045	-0.125	0.005	0.045	-0.126
	(0.059)	(0.045)	(0.094)	(0.060)	(0.045)	(0.094)
GDP per cap	-0.115	0.051	-0.295**	-0.115	0.051	-0.294**
	(0.084)	(0.064)	(0.133)	(0.084)	(0.064)	(0.133)
Distance	0.173	0.025	0.691***	0.161	0.030	0.633**
	(0.166)	(0.126)	(0.262)	(0.182)	(0.138)	(0.287)
Contiguity				-0.067	0.024	-0.311
				(0.394)	(0.299)	(0.621)
R-Adj.	0.037	0.029	0.181	0.037	0.029	0.182
N	126	126	126	126	126	126

Notes: OLS regressions of equation 12 with HS8 level fixed effects. Standard errors are reported in parentheses. * (**) (***) indicates significance at the 10 (5) (1) percent level.

analysis with interesting policy implications. We leave this question for our future work.

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