The Agglomeration of Exporters by Destination*

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November 2010

Abstract

Precise characterization of informational trade barriers is neither well documented nor understood. Using Russian customs data, we find exporting firms agglomerate geographically with respect to their shipment's destination in addition to agglomeration around ports, suggesting behavior responding to a trade barrier. To account for this fact, we build on Melitz (2003) and Chaney (2008) by postulating an externality in the international shipping of goods. We test the model's prediction on region- and state-level exports using Russian and U.S. data. Our model accounts for up to 40% more of the variation than in gravity-type models without agglomeration.

JEL classification: D23, F12, L29

Keywords: agglomeration, distribution, exports, international trade, location, Russia

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*Thanks to Thomas Holmes, Yelena Tuzova, Anton Cheremukhin, and seminar participants at Vasser College, Washington State University, and the New York Economics Association annual meeting. We also thank Qianqian Wang and Pavan Dhanireddy for research assistance, and Jeremy Sage for help with ArcGIS.

1 Introduction

One of the biggest unsolved problems in international trade is the size and nature of barriers to trade. Great theoretical and empirical strides have been made by country-level and firm-level studies, yet the precise characterization of barriers to trade continues to elude researchers.

We take the next step in understanding international trade barriers. We document that exporting firms agglomerate geographically with respect to their shipping destinations. This agglomeration is in addition to the agglomeration of exporters around domestic ports (Glejser, Jacquemin and Petit 1980; Nuadé and Matthee 2007). We develop a theory to account for this destination-specific agglomeration that is supported with transaction-level data from Russia. We then test our theory using region-level data from Russia and state-level data from the United States.

Building on a foundation of Melitz (2003) and Chaney (2008), our theory posits that the transaction or transportation cost of an export shipment depends on both the bilateral distance and the weight of other firms' exports to the same country. In our model, aggregate region-country export weight is an externality, allowing individual firms to exploit group economies of scale in shipping costs, and thus leading to agglomeration by destination.

We use the transaction-level Russian export data to show evidence of the reasonableness of this hypothesis. The data show that, by far, most shipments are small in weight. As long as shipping prices to exporters include a fixed cost per container (buying the container) or per destination (permit to unload) and are based on weight (Micco and Pérez 2002), then there are shipping cost savings in grouping small exports together on a boat or plane heading to the same destination. Alternatively, aggregate export weight may be thought of as the result of an informational spillover about foreign market access. The exact nature of the externality is not important for our model or results.

In our model, an exporter may skip over a destination that has more appealing demand in order to achieve economies of scale in consolidated shipments to a less preferred destination. All else the same, this creates variation in the destination choices of otherwise identical firms in different regions. Lawless (2009) documents such skipping of "preferred" destinations at the national-level, but his evidence is inconsistent with the theory developed in Eaton, Kortum and Kramarz (2010).

Our theory better accounts for the geographic pattern of exporting by creating a regional hierarchy of export destinations that differs from the national hierarchy.

We find that on the aggregate region-level export data from Russia, our model with agglomeration accounts for 10% more of the variation in export share than the benchmark model. Using U.S. state export data, our model accounts for 40% more of the variation. Therefore, we have uncovered evidence of a barrier to trade large enough for firms to respond to by agglomerating and we provide theoretic and empirical justification for it.

The transaction-level data that motivates our theory is from Russia. We choose to study Russian exporters because Russia is a geographically large and diverse country. It borders fourteen countries (with China and Ukraine being major trading partners), has four coasts (Arctic Ocean, Pacific Ocean, Baltic Sea, and Black Sea) and diverse economic subregions. Finally, the laws in Russia limit the movement of firms regionally (see Appendix A for a more detailed description). This allows us to model a firm's export destination decision without also modeling its location decision within Russia

Because we are aware that Russian data may be systematically different from other countries' data for a number of reasons (relationship with former Soviet countries, corruption, remnants of central planning, etc.), we test the macro-level predictions of our theory on the World Institute for Strategic Economic Research's (WISER) Origin of Movement U.S. state export data (OM). This data contains export information for all 50 U.S. states and the same 179 countries that we use with the Russian data.

2 Facts on the Location & Agglomeration of Russian Exporters

In this section, we show that 1) exporters are clustered regionally given output and the location of ports and 2) exporters shipping to the same destination are further clustered. To do this, we use Russian customs data. Because of the uniqueness of this data, we begin by describing it.

2.1 The Russian Data

To document the existence of destination-specific agglomeration of exporters, we use 2003 data from the Russian External Economic Activities (REEA) set reported by Russian customs. The REEA data are shipment-level customs data of uniquely identified firms, providing value of goods shipped (in 2003 USD), weight of shipment, exporter location within Russia, and destination country. We assign each exporter to one of Russia's 89 federal regions because we are not able to pinpoint exporter location by exact physical address.[1] This limitation forces us to conduct clustering tests on the region-level. See Appendix A for a detailed description of the political organization of Russia and also for a table listing the regions.

Goods are classified according to the Commodity Classification for Foreign Economic Activities (CC-FEA). We only consider manufacturing exports because firms that exported natural resources were necessarily located in the region endowed with those resources (Bradshaw 2008). In addition, we only use manufacturing data so that we can later have a direct comparison with the OM data for the United States. Cassey (2009) shows manufacturing data are the only data that can be reliably used for the state of production of the export instead of the state where the export began its journey abroad, whereas agriculture and mining data are not reliable.

From information on the customs form, we believe we are tracking firms who are making the export decision. This includes producing firms, distributors, and wholesalers. We eliminate observations in which the "originating firm" is located outside of Russia since we believe they indicate re-exports rather than true Russian exports, as well as to be consistent with the U.S. data. Since we care about the exporters' decision of where to ship goods regardless of whether they produce the export or just sell it, it does not matter that we do not distinguish between producing firms, wholesalers, and distributors in our sample.

To check for consistencies in the data, Schmeiser (2010) compares the REEA data with product data from the United Nations and finds 88% agreement at the country-level. Schmeiser (2010) shows that export patterns found in our data are similar to Colombian (Eaton, Eslava, Kugler

[1] Russia's federal regions are somewhat similar in geographic scope to U.S. states. The number of regions has decreased since 2003 because of mergers. Analyzing trends, such as FDI flows into Russia, are often performed on the regional level, see for example Broadman and Recanatini (2001).

and Tybout 2008) and French (Eaton, Kortum and Kramarz 2010) data. We therefore assume any missing data are not greatly influencing or biasing our interpretation of results, in particular towards any geographic region.

We combine the REEA data with information about the overall economy in each region using *Russia: All Regions Trade & Investment Guide* (CTEC Publishing 2004, 2006). We use data on each region's gross domestic product and the value of industrial output. We also use the *World Economic Outlook Database* (IMF 2006) for GDP information for the 179 countries in our sample. Finally, we calculate the great circle distance from the capital of each Russian region to the capital of each country in the world.

2.2 Russian Exporters and Exports

First, consider the number of exporting firms by region. Figure 1 shows that the regional concentration of Russian manufacturing exporters is diverse. The majority of exporters are located either around Moscow and St. Petersburg or the Kazakhstan/Mongolia/China border. Nine regions did not have any reported exporting firms in 2003. Figure 1 shows that in Russia, as elsewhere, many exporting firms are located near major ports. However, the figure also shows that there are regions with many exporting firms that are not located near a major port. A map of Russia with major rivers and railroads is in appendix A.

The top destinations for Russia exports in 2003 were, in order: China, United States, United Kingdom, Japan, Ukraine, Kazakhstan, Turkey, Netherlands, Germany, and Iran. Of these, only Ukraine and Kazakstan were part of the Soviet Union. Additionally, Russia does not currently have a Warsaw Pact nation as a top destination.[2] Because we do not see evidence of favored trade relations with former Soviet or Eastern bloc countries, we do not treat them any differently than Western countries.

Federal laws in Russia severely limit the ability of Russian firms to change region (Botolf 2003). Because of this, firms choose how much to export to each country in the world, taking their location as given. Furthermore, because the Soviet Union did not trade with western countries, we believe it is likely that the Soviet central planners chose firm locations for reasons other than the expansion

[2]Soviet trade was with countries of similar ideology such as Yugoslavia and Poland.

Figure 1: Number of exporting firms, by region. Cut-offs correspond to quintiles so that there are an equal number of regions in each category. See the appendix for a map of Russia with the regions labeled and railways indicated.

of trade (see Huber, Nagaev and Wörgötter (1997) and Bradshaw (2008)). Other evidence that international trade was *not* important in Soviet economic planning is that the large Pacific port of Vladivostok, home of the Soviet Pacific Fleet, was closed to foreign vessels until 1991.

2.3 The Geography of Russian Exporters

To show that exporters are clustered, we first use the customs data to calculate the number of firms in each region that export anywhere in the world. Figure 1 shows this as well as the location of ports, bodies of water, and neighboring countries, without modification for population or GDP. Cut-offs for the groups are determined so that each group has the same number of regions.

Next, we weight the exporter count observations by regional GDP. We compare each region's exporter count to the overall mean. Figure 2 highlights regions with a concentration of exporters far from the mean. Darker colors indicate regions whose exporter count, weighted by GDP, is much larger than the mean. As seen in the figure, there exists regions in Russia that have statistically significantly more exporters than expected based on regional GDP. Furthermore, many of these export-concentrated regions do not have a major port. Figure 2 also shows there are regions (weighted by GDP) with less exporting firms than the mean. These regions, indicated with the lightest shades, are not nearly as far below the mean as the regions much larger than the mean.

We use this information to calculate the Moran's I statistic for spatial autocorrelation. The expectation of the statistic is $-1/(89-1)$ under a GDP-weighted random distribution of exporters to Russia's 89 regions. With our data, the Moran's I statistic for spatial autocorrelation is 0.16^{*} ($z-$ *score* $= 6.37$) indicating that we reject spatial (GDP-weighted) randomness with 99% confidence. Additionally the clustering is not based on regions that have major ports. We conduct two other tests to confirm this result. They are in appendix C.

To see what the clustering is based on, consider a specific example: the location of Russian firms that export to the United States and the location of Russian firms that export to Canada. We choose these two countries because they have similar economies (though the United States is much larger), distance from Russia, and consume similar goods (at the 2 digit level they share six of the top ten exported goods). The Moran's I for the location of Russian exporters shipping to the United States is 0.04^{***} ($z = 1.93$) and it is 0.03^{***} ($z = 1.68$) for Canada. Thus there is

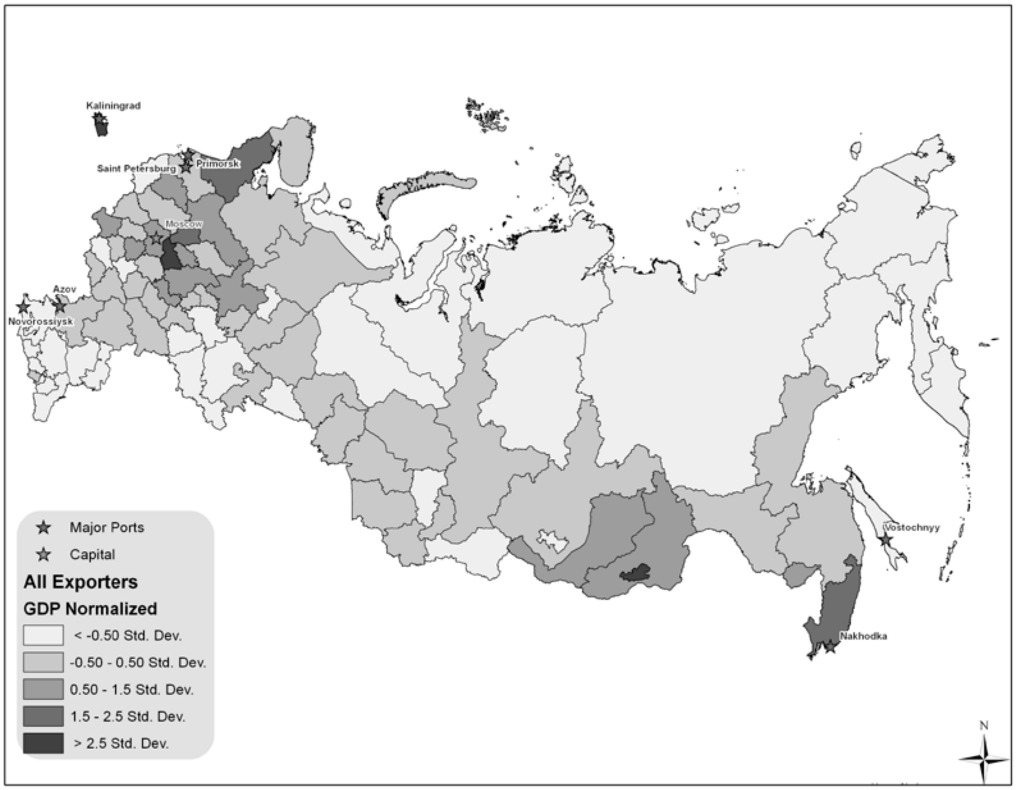
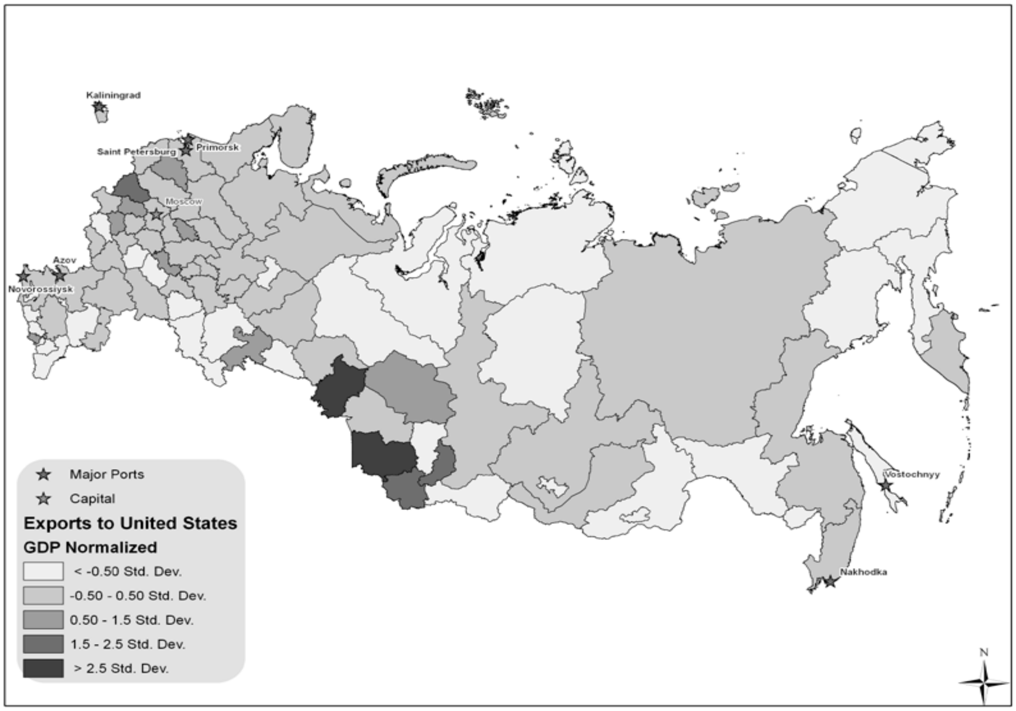


Figure 2: Deviations from the average number of exporting firms, by region, weighted by GDP. Moran's I (89) = 0.16^* ($z - score = 6.37$).

clustering for exporters to the United States and Canada with 90% confidence. To see that it is *not* the same regions (and therefore the same firms within a region) that specialize in exporting to both countries, see figure 3.

Figure 3 shows the deviation from the mean number of firms that export to the United States and the mean number of firms that export to Canada. Notice that there are more regions in Russia that have exporters shipping goods to the United States than Canada, but that is not surprising given the difference in GDP and that the United States is the second largest receiving country of Russian exports. The second fact is that the regions where exporters shipping to the United States are most concentrated (shaded black in figure 3 and indicating more than 2.5 standard deviations from the mean) are *not* the same regions where exporters to Canada are concentrated. Therefore Russian exporters to the United States are clustered in a different pattern than the Russian exporters to Canada.

UNITED STATES



CANADA

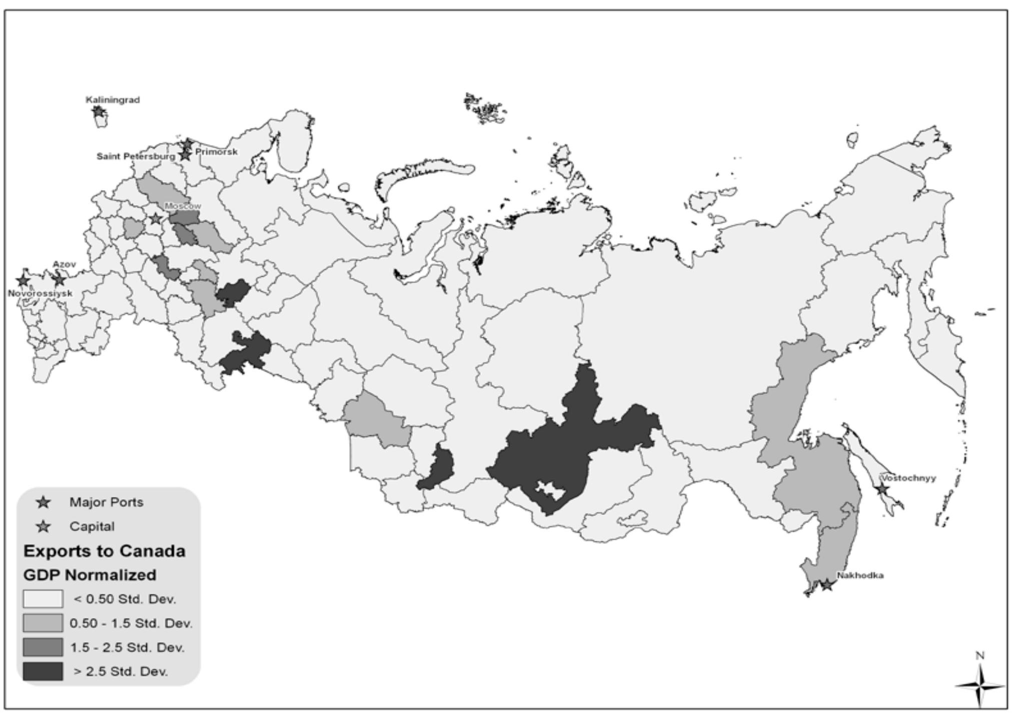


Figure 3: Deviations from the average number of exporting firms, by region, weighted by GDP. For the Unites States, Moran's I (89) = 0.04*** ($z = 1.93$) and for Canda, Moran's I (89) = 0.03*** ($z = 1.68$).

To see that this clustering by destination of exported shipments holds more generally, we consider the location of the destination relative to Russian firms using the gravity equation. Though the gravity equation takes several forms, we use the version derived by Anderson and van Wincoop (2003). In this formulation, the exponent on exporter GDP and importer GDP must be one, so we divide both sides by exporter and importer GDP. As recommended by Feenstra (2004, p. 161), we insert export-specific and import-specific sets of binary variables to account for the unobservable multilateral resistance terms. Using Ordinary Least Squares (OLS), we estimate,

$$\log \frac{X_{ij}}{Y_i Y_j} = \underset{(.881)}{-14.342^*} - \underset{(.110)}{1.32^*} \log D_{ij} + \sum_{i=2}^{89} \kappa_i S_i + \sum_{j=2}^{179} \delta_j T_j + \varepsilon_{ij} \tag{1}$$
$$N = 3028, \quad R^2 = 0.61, \quad RMSE = 2.03$$

where * indicates significantly different from zero at with 99% confidence and the standard errors are robust. The regression results suggest that the overall explanatory power of the gravity equation to account for Russian regional exports is low compared to the $R^2 \geq 0.7$ common in country-level data sets that often do not use binary variables to increase the goodness of fit.[3]

We consider the relatively low R^2 from using subnational data (compared to the R^2 on national data) in a gravity equation evidence that something is missing. Given that many theories of trade predict a gravity equation-like relationship—Anderson (1979) and Chaney (2008) for example—we have documented a weakness in existing theory. See appendix D for the estimation of gravity nonlinearly to address the fact that only 19% of our possible observations are nonzero.

Using customs data from Russia, we have shown that Russian exporters are clustered but that these clusters differ depending on the country receiving the exports. Next, we develop a theory to account for this fact.

[3] The estimates for a "naive" gravity equation are

$$\log X_{ij} = \underset{(0.578)}{-0.992} + \underset{(0.043)}{0.564^*} \log Y_i + \underset{(0.022)}{0.290^*} \log Y_j - \underset{(0.065)}{1.149^*} \log D_{ij} + \varepsilon_{ij}$$
$$N = 3028, \quad R^2 = 0.153, \quad RMSE = 2.449$$

3 A Theory of Exporter Agglomeration Based on Shipment Destination

We develop of theory of trade where exporters agglomerate with other exporters shipping to the same location due to international shipping costs. Agglomeration arises because firms achieve economics of scale in transportation when their shipments are consolidated with others going to the same destination. In this sense, we model a generalized transportation cost concept. Our model is a monopolistic competition trade model in the spirit of Melitz (2003) and Chaney (2008) but modified to incorporate agglomeration as in Ottaviano, Tabuchi and Thisse (2002) and Fujita and Thisse (1996).

3.1 Motivation and Evidence

Our theory may take a few forms in the real world. The first version is a traditional treatment of an externality. As in Head, Ries and Swenson (1995), agglomeration occurs within a region because of knowledge spillovers that are limited in geography. In our case, the knowledge that is spilled is about exporting to a specific country (because of good contacts, translation, or effective bribes paid continually) regardless of the exporter's product or industry.

A second story can be supported with our Russian data. In this story, firms benefit from economies of scale in transportation and shipments. Because of containerization in rail, ship, and air transportation, there is a fixed size to the shipment.[4] As documented in Besedeš and Prusa (2006), most shipments are small.

This is true in our Russian data as well. Table 1 shows the quartiles for shipments by weight. As the table shows, 50% of shipments weighed less than 185 kg (407 lbs) and 25% or less than 14 kg (31 lbs). Thus most shipments are small, with a few huge shipments.

Though table 1 is useful for showing the frequency of small shipments, it does not control for industry. To control for industry, we regress export value on *shipment* weight with a set of industry binary variables.

[4] Korinek and Sourdin (2010) show that shipping companies quote transportation rates in cost per container.

Table 1: Weight of Transaction-level Shipments, by Quartile

Quartile (%)	Weight (kg)
25	14
50	185
75	4716
100	1,597,020,500
N	115,133

$$\log exports_{ij} = \underset{(.022)}{3.264^*} + \underset{(.001)}{.684^*} \log weight_{ij} + \sum_{k=2}^{56} \iota_k Ind_k + \mu_{ij} \quad (2)$$
$$N = 115,053, \quad R^2 = 0.73, \quad RMSE = 1.152$$

The relationship between value and weight, though positive, is not particularly strong. The correlation of exports and weight at the shipment-level is only 0.57. As (2) shows, within industry, the heavier the shipment, the more valued the sale. This makes sense, but the fact that the coefficient on weight is not larger suggests that there is additional benefit not measured.

Perhaps the additional value is from grouping shipments together. Because most shipments are small, exporters cannot fill a standardized container or a ship on their own. Hence if firm A is exporting to China, firm B can add its goods to the shipment. Either the transportation company would be willing to sell its remaining room to firm B below average cost or firm A would be willing to sell its extra container room. Thus both firm A and B pay a lower transportation cost than if they shipped alone. Micco and Pérez (2002) find evidence of this by estimating that a doubling of trade volume weight from a particular port reduces transportation costs on that route by 3–4%. They say "In general, even though most of these economies of scale are at the vessel level, in practice they are related to the total volume of trade between two regions."

At the region-level, our model formally considers this informal logic that has precedent in the agglomeration literature. Regardless of which of these motivating tales is the most reasonable, the modeling of them is the same. The particular stories above should not be taken too seriously. For example, we know that some countries require that imports in containers only come from one firm. But we think they exemplify the spirit of why we posit an externality.

3.2 Consumer's Problem

Our model economy has N non-symmetric destination countries spread spatially across the world. We do not model the characteristics of countries other than that each is a passive consumer of Russian goods and each differ in size and location. The representative consumer in each country j has utility on the consumption of an aggregate good of quantity C_j defined by

$$C_j = \left(\int_{\omega \in \Omega_j} c_j(\omega)^{\frac{(\sigma-1)}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

where the elasticity of substitution between goods ω is $\sigma > 1$ and Ω_j is the set of Russian goods available for consumption in country j. The consumer maximizes utility given the availability of goods and prices such that

$$\int_{\omega \in \Omega_j} p_j(\omega) c_j(\omega) d\omega \leq Y_j.$$

Demand for Russian goods in each country j is

$$c_j(\omega) = Y_j \frac{P_j^{\sigma-1}}{p_j(\omega)^{\sigma}}.$$

The aggregate price index in country j is

$$P_j = \left(\int_{\omega \in \Omega_j} p_j(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}.$$

Countries differ exogenously in their income endowment Y_j and their spatial location. They differ endogenously in the availability of Russian goods Ω_j, their aggregate price index P_j, and their aggregate consumption C_j. Each foreign country produces one distinct good with constant-returns-to-scale technology.

3.3 Russian Manufacturing Firms

There is a continuum of Russian exporters distributed spatially throughout Russia. These exporters differ in manufacturing productivity in addition to their location in space. Firm productivity, φ, is drawn from a Pareto distribution and cannot be changed:

$$P(\tilde{\varphi} < \varphi) = G(\varphi) = 1 - \varphi^{-\gamma}; \qquad g(\varphi) = \gamma\varphi^{-1-\gamma}.$$

where $\gamma > \sigma - 1$. Each firm, identified by their productivity φ and the region where they are located i, produces a unique good, ω.

There is a per-unit cost of production w_i that is common to all firms in a region, but differs across regions. (We believe this is plausible given the relative lack of labor mobility within Russia.) Because of the rigidness of Russian law, we assume that firms are not free to change location. Finally, there is a one-time start-up fixed cost, f_{ij}, associated with exporting from each region i in Russia to each country j in the world.

Given their productivity, the cost of production, and the fixed cost to export, a firm in region i maximizes profits in each market j it sells to by choosing the price, $p_{ij}(\varphi)$, and quantity, $x_{ij}(\varphi)$, in that market:

$$\pi_{ij}(\varphi) = p_{ij}(\varphi)x_{ij}(\varphi) - w_i\left(\frac{x_{ij}(\varphi)}{\varphi}\tau_{ij}(W_{ij}, \cdot) + f_{ij}\right). \tag{3}$$

Notice there is a region-destination variable transportation cost, $\tau_{ij}(W_{ij}, \cdot)$. This cost is not a constant, but a function of the *aggregate weight* W_{ij} of exports from region i exporting to j, among other variables such as physical distance which will be specified later and are now represented with a dot. Turning τ_{ij} into a function of other exporter activities is the primary theoretical contribution of this work. We assume $\tau_{ij}(W_{ij}) > 0$, $\tau'_{ij}(W_{ij}) < 0$, and $\tau''_{ij}(W_{ij}) > 0$. If the solution to (3) is not positive, then the firm does not export to j.

The addition of the bilateral weight of exports W_{ij} in the transportation cost is the agglomeration effect. We posit its existence is due to savings from consolidated shipments. Weight is a primary consideration in shipping costs, and shipping costs show economics of scale. Our specification of the agglomeration effect is external to the firm, agreeing with Ottaviano et al. (2002).

3.4 Equilibrium

Our equilibrium concept uses Bertrand competition between the monopolistic competitors.[5] Bertrand competition gives the price for each firm's output in each destination:

$$p_{ij}(\varphi) = \frac{\sigma}{\sigma - 1}\frac{w_i}{\varphi} \times \tau_{ij}(W_{ij}, \cdot).$$

Unlike the constant markup common in Melitz-style models, the per-unit price charged by each firm in a destination also depends on our agglomeration term W_{ij}. Because of the economies of scale in transportation, the more weight is being shipped, the lower the transportation cost paid by each firm and the lower the price charged to consumers.

From the zero profit condition of Bertrand competition, there exists a threshold productivity for each region exporting to each destination such that $\pi_{ij}(\varphi^*_{ij}) = 0$:

$$\varphi^*_{ij} = \lambda_1 \left(\frac{w_i f_{ij}}{Y_j}\right)^{\frac{1}{\sigma-1}} \frac{w_i}{P_j} \times \tau_{ij}(W_{ij}, \cdot)$$

where the constant $\lambda_1 = [(\frac{\sigma}{\sigma-1})^{1-\sigma} - (\frac{\sigma}{\sigma-1})^{-\sigma}]^{\frac{1}{(\sigma-1)}}$.

Additionally we assume that market clearing conditions hold

$$x_{ij}(\omega) = c_{ij}(\omega)$$

and that trade is balanced

$$\sum_i \int_\omega x_{ij}(\omega) = x^*_j$$

where x^*_j is a constant-returns-to-scale good produced good in country j.

The equilibrium aggregate price index for country j is given by the prices of firms from each region that are above the productivity threshold and export to country j:

$$P_j = \left(\sum_i \int_\varphi p_{ij}(\varphi^*_{i,j})^{\frac{\rho}{\rho-1}} Y_i dG(\varphi)\right)^{\frac{\rho-1}{\rho}} = \lambda_2 \theta_j Y_j^{\frac{1}{\gamma} - \frac{1}{(\sigma-1)}} \quad (4)$$

[5] Results are the same under Cournot competition because there is a continuum of goods.

where $\lambda_2 = \lambda_1^{\frac{\gamma+1-\sigma}{\gamma}} (\sigma - 1 - \gamma)^{1/\gamma} \left(\gamma(\frac{\sigma}{\sigma-1})^{1-\sigma}\right)^{-1/\gamma}$ and $\theta_j = \left[\sum_i Y_i (w_i f_{ij})^{1-\frac{\gamma}{(\sigma-1)}} [w_i \tau_{ij}(W_{ij}, \cdot)]^{-\gamma}\right]^{-1/\gamma}$. As in Chaney (2008), we interpret θ_j as a weighted trade barrier or multilateral resistance as in Anderson and van Wincoop (2003); λ_2 and λ_1 are constants.

Using the equilibrium aggregate price (4), we calculate the other equilibrium variables in the model. The cutoff productivity for firms in i exporting to j is:

$$\varphi_{ij}^* = \lambda_3 Y_j^{-1/\gamma} (w_i f_{ij})^{1/(\sigma-1)} \frac{w \tau_{ij}(W_{ij}, \cdot)}{\theta_j}$$

where the constant $\lambda_3 = \lambda_1 / \lambda_2$. The value of exports from firm φ in region i to j is:

$$p_{ij}(\varphi) x_{ij}(\varphi) = \lambda_4 Y_j^{\frac{\sigma-1}{\gamma}} \left(\frac{\varphi \theta_j}{w_i \tau_{ij}(W_{ij}, \cdot)}\right)^{\sigma-1}$$

where $\lambda_4 = \left(\lambda_2 \frac{\sigma-1}{\sigma}\right)^{\sigma-1}$.

Finally, equilibrium aggregate exports to country j from region i are:

$$X_{ij} = \int_{\omega \in \Omega_j} p_{ij}(\omega) x_{ij}(\omega) d\omega = \int_{\varphi_{ij}^*} p_{ij}(\varphi) x_{ij}(\varphi) Y_i dG(\varphi)$$

$$= Y_i Y_j \left(\frac{w_i \tau_{ij}(W_{ij}, \cdot)}{\theta_j}\right)^{-\gamma} (w_i f_{ij})^{1-\frac{\gamma}{(\sigma-1)}} \lambda_5. \tag{5}$$

where $\lambda_5 = \frac{\lambda_4}{\gamma} \frac{1}{\gamma - (\sigma-1)} \lambda_3^{\sigma-1-\gamma}$.

Our agglomeration effect W_{ij} shows up in equation (5) in two places. It shows up directly in $\tau_{ij}(W_{ij})$ but also indirectly in $\theta_j = \left[\sum_i Y_i (w_i f_{ij})^{1-\gamma/(\sigma-1)} [w_i \tau_{ij}(W_{ij}, \cdot)]^{-\gamma}\right]^{-1/\gamma}$.

4 Counterfactual and the Gravity Equation

We derived our theoretical counterpart to gravity in equation (5). We take this prediction to the Russian data at the region-level. To do this, we convert (5) into reduced form by taking logs,

$$\log X_{ij} = \log Y_i Y_j - \gamma \log \tau_{ij}(W_{ij}, \cdot) + (1 - \gamma - \frac{\gamma}{\sigma - 1}) \log w_i + \gamma \log \theta_j + (1 - \frac{\gamma}{\sigma - 1}) \log f_{ij} + \log \lambda_5.$$

We rewrite to get,

$$\log \frac{X_{ij}}{Y_i Y_j} = \alpha + \beta_1 \log \tau_{ij}(W_{ij}, \cdot) + \beta_2 \log w_i + \beta_3 \log \theta_j + \varepsilon_{ij} \tag{6}$$

where $\alpha = \log \lambda_5$, $\beta_1 = -\gamma$, $\beta_2 = 1 - \gamma - \frac{\gamma}{\sigma-1}$, $\beta_3 = \gamma$, and $\varepsilon_{ij} = (1 - \frac{\gamma}{\sigma-1}) \log f_{ij}$.

In order to estimate (6), we assume a functional form for how the weight of aggregate region-country shipments W_{ij} relates to bilateral trade costs τ_{ij}. We assume trade costs are a function of physical distance, D_{ij}, and aggregate region-country shipping weight, but nothing else. To our knowledge, this is the first time weight has been used as a regressor for exports. Often the gravity literature uses variables such as common language, colonial history, location of overseas trade offices, and exchange rates as barriers to trade. But these variables do not apply to our data because there is no variation in these across regions within Russia. Therefore, we assume

$$\tau_{ij}(W_{ij}, \cdot) = D_{ij} \times W_{ij}^{-\eta}. \tag{7}$$

This technology's modeling nests the gravity model by setting $\eta = 0$. Later, we test if $\eta = 0$.

We have data on X_{ij}, Y_i, Y_j, W_{ij}, and D_{ij}. We do not have reliable data on w_i and f_{ij}, and therefore cannot calculate θ_j. We use a set of region-specific binary variables S_i to account for w_i and any other unobserved unilateral region features. We use a set of country-specific binary variables T_j to account for θ_j and any other unobserved unilateral country features. We let the bilateral fixed cost be the error term.

$$\log \frac{X_{ij}}{Y_i Y_j} = \underset{(.881)}{-14.342^*} - \underset{(.101)}{.805^*} \log D_{ij} + \underset{(.014)}{.253^*} \log W_{ij} + \sum_{i=2}^{89} \kappa_i S_i + \sum_{j=2}^{179} \delta_j T_j + \varepsilon_{ij} \tag{8}$$

$$N = 3028, \quad R^2 = 0.67, \quad RMSE = 1.87$$

Compare equation (8) to the original gravity equation (1). In addition to our agglomeration term being significant at the 99% level, the R^2 improves from .61 to .67.[6,7] Therefore our model

[6] This is the adjusted R^2.

[7] Some of the agglomeration literature uses firm count (which makes less sense in our model than weight). Replacing the weight of shipments from i to j with the mass of firms exporting from i to j yields a statistically significant coefficient estimate on mass at the 99% level.

with an agglomeration term based on the aggregate weight of shipping costs accounts for 9.8% more variation in export share than (1).

Because of our choice of how weight enters the transportation cost function (7), our model predicts that the coefficient of physical distance D_{ij} is equal to $-\gamma$ and the coefficient on aggregate export weight W_{ij} is equal to $\gamma\eta$. From these two predictions, we calculate $\eta = 0.314$, which is economically significant. We conduct a nonlinear Wald test of whether $\eta = 0$. We reject that $\eta = 0$ with 99% confidence ($F(1, 2795) = 46.06$), so η is statistically significant as well. This suggests our choice of technology is reasonable.

Another endorsement of our model comes from our estimate of γ. We cannot reject that $\gamma = 1$ with 99% confidence which agrees with Axtell (2001) who reports that γ is near one for many countries. Using our estimate on γ and Chaney's estimate for $\frac{\gamma}{\sigma-1}$, we calculate $\sigma = 1.40$. This is consistent with the requirement that $\gamma > \sigma - 1$ and that $\sigma > 1$. At first, σ seems too low for an estimate of the elasticity of substitution, since it implies very large markups in price over marginal cost. Additionally our σ is low compared to the 3 to 8 range estimated by Hummels (2001), but Hummel's estimates are within a product category whereas ours is for all manufactured tradables. Furthermore, as argued by Rauch (1999), if there are informational costs to trade in the data that do not appear as physical distance as in equation (7), then the estimate for σ will be low.

5 Application to U.S. State exports

Though we established the facts about agglomeration of exporters around the destination of their shipments and motived our model using transaction-level customs data from Russia, there is nothing in the reduced form equation (6) that requires customs data. Therefore, we take our model to another regional export data set. The data set is the Origin of Movement export data for U.S. states. We do this to check that our previous results are applicable to a wider set of countries than Russia.

A detailed description of the OM data is in Cassey (2009). Because of his findings on data quality, we limit our observations to manufactured exports only. We also restrict our sample to 2003 to match the Russian data. The same sample of countries is used except that the United

States is no longer a destination. Beginning with the benchmark gravity equation in (1) and using OLS, we find:

$$\log \frac{X_{ij}}{Y_i Y_j} = \underset{(1.27)}{2.29} - \underset{(.138)}{2.07^*} \log D_{ij} + \sum_{i=2}^{50} \kappa_i S_i + \sum_{j=2}^{178} \delta_j T_j + \varepsilon_{ij} \tag{9}$$
$$N = 6993, \quad R^2 = 0.54, \quad RMSE = 1.28$$

The estimated coefficient on distance is much larger than for the Russian data, and the constant is not statistically significant at the 1% level. For us, the relevant statistic is $R^2 = .54$.

Applying the U.S. data to (6) yields:

$$\log \frac{X_{ij}}{Y_i Y_j} = \underset{(.959)}{-9.95^*} - \underset{(.103)}{.967^*} \log D_{ij} + \underset{(.006)}{.433^*} \log W_{ij} + \sum_{i=2}^{50} \kappa_i S_i + \sum_{j=2}^{178} \delta_j T_j + \varepsilon_{ij} \tag{10}$$
$$N = 6971, \quad R^2 = 0.76, \quad RMSE = 0.93$$

The R^2 increases from .54 in the benchmark to .76 in our model, an increase of 40%. (The results for the data pooled over 1997 to 2008 are essentially the same.) We estimate $\eta = 0.448^*$. As with the Russian data, we can confidently reject that $\eta = 0$ ($F(1, 6747) = 82.29$). Furthermore, the estimated coefficients in equation (10) are similar to those using the Russian data in (8) whereas the same is not true for the benchmark. Another encouraging result is that our estimate for γ is again not statistically different from one ($F(1, 6747) = .1$) as before, but with more confidence. Furthermore, our estimate is close to the 0.99 to 1.10 range for U.S. data reported in Axtell (2001) whereas the benchmark is too high. Finally, with the U.S. data, we estimate $\sigma = 1.5$.

Applying the OM state export data to our model strengthens the results achieved with the Russian data.

6 Conclusion

The theoretical and empirical international trade literature typically studies flows at the country-level. However more recent papers such as Eaton, Kortum, and Kramarz (2010); Bernard and Jensen (2004); Tybout (2003); and Arkolakis and Muendler (2007) study firm-level export decisions.

All of these articles study the production and technology characteristics of the firm and their export decision—what to export, how much to export, and to which countries. The findings from this work indicate there are barriers to exporting whose precise characterization continues to elude researchers.

We use the physical location of exporting establishments in Russia to take the next research step in understanding the international barriers to trade. We assign Russian exporters to one of Russia's 89 regions and test to see if there is agglomeration. We find there is agglomeration of exporters, not only in general and around ports, but also in terms of the destination that exports are shipped to. We believe this clustering of exporters by destination indicates firm behavior confronting a particular barrier to trade.

We posit that this agglomeration of exporters by destination is an externality from how-to-export information spillovers or economies of scale in shipping costs. Our combination of localization techniques and externality modeling from industrial organization with the tools from firm-level international trade models yields new empirical and theoretical insights into the nature and size of barriers to international trade, and the behavior of firms to overcome these barriers.

Our model's prediction is verified with the Russian data and outside sources, and our model accounts for more of the variation in export share than the benchmark Anderson and van Wincoop (2003) or Chaney (2008) gravity-type model. We then test our model on U.S. state export data and are able to account for 40% more variation in export share than the benchmark. The documenting of agglomeration by destination and the confirmation of our model takes a step toward understanding the size and nature of the international barriers to trade.

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Appendices

A The Political Organization of Russia

In 2003, Russia had 89 federal regions. These regions were separated into 49 oblasts (provinces), 21 republics, 6 krais (territories), 10 okrugs (autonomous districts), 1 autonomous oblast, and 2 federal cities (Moscow and St. Petersberg). The divisions are based on ethnic groups and history. Each region has equal representation in the Federal Assembly, though there are differences in autonomy. However these differences are minor (and decreasing over time) because each region is attached to one of eight federal districts administered by an envoy of Russia's President. The districts are designed to oversee regional compliance with federal laws.

Most taxes are set federally. In 2003, regions could set corporate property tax, gambling business tax, and transport tax within bounds established federally (Russia 2006, p. 955). Exports of goods from Russia are subject to a value-added tax of 0% throughout Russia (Russia 2006, p. 960), except on some exports of oil and natural gas. Export customs duty rates are set federally as well (p. 961).

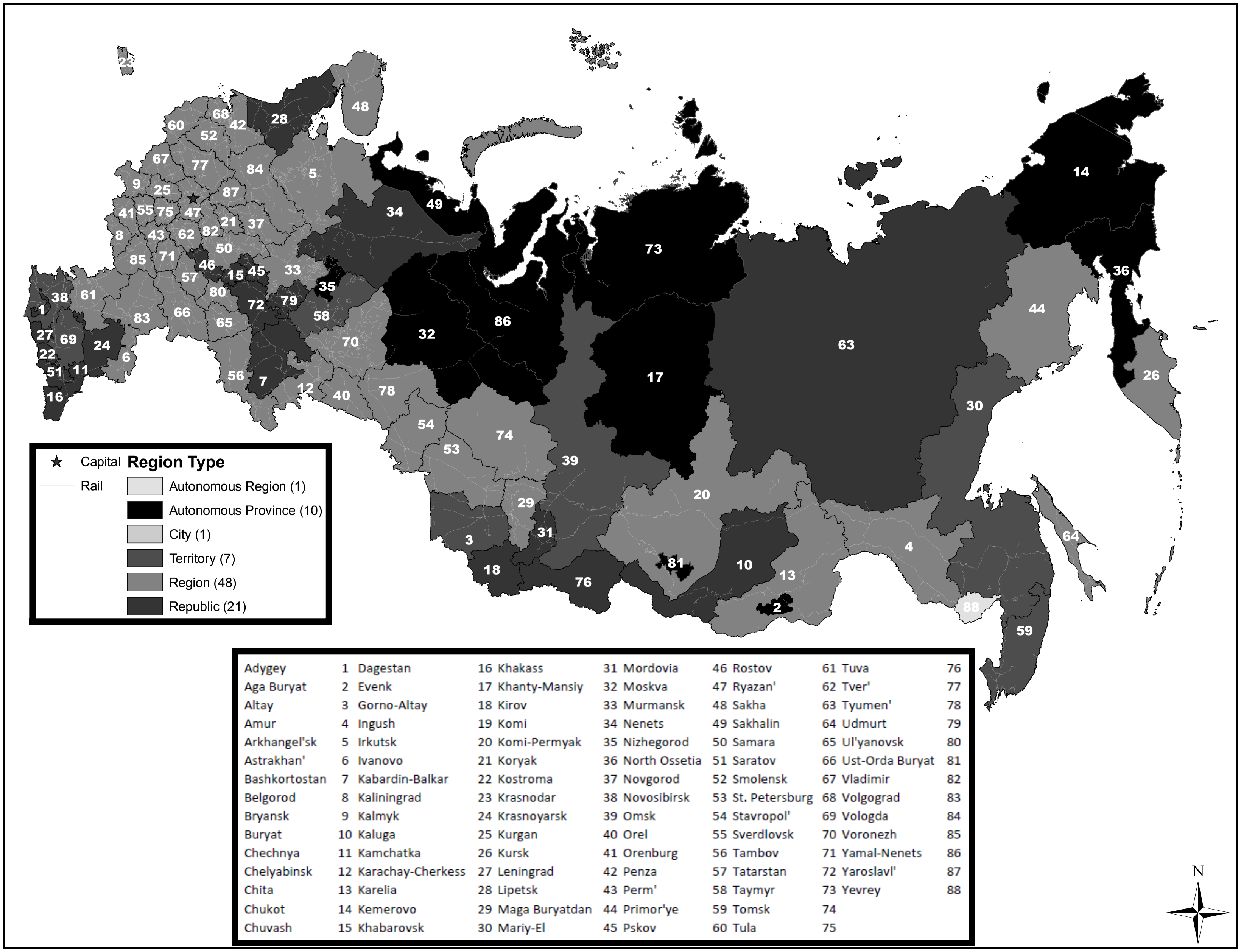

Figure 4: Russia's Regions in 2003. The City of Moscow Region is included in the map only as the star and not listed separately.

Table A.1: Geographic Regions

Region	Type	GDP (millions)	Region	Type	GDP (millions)
Adygeya	Republic	352.8	Mordovia	Republic	1281.7
Agin-Buryat	Autonomous Okrug	77.8	Moscow	Federal City	84742.3
Altai	Krai	3130.4	Moscow	Oblast	15517.4
Altai	Republic	269.6	Murmansk	Oblast	2834.3
Amur	Oblast	1901.5	Nenets	Autonomous Okrug	876.1
Arkhangelsk	Oblast	3735.1	Nizhny Novgorod	Oblast	7720.1
Astrakhan	Oblast	1884	North Ossetia-Alania	Republic	726.8
Bashkortostan	Republic	54851.7	Novgorod	Oblast	1356.1
Belgorod	Oblast	2766.4	Novosibirsk	Oblast	5797.2
Bryansk	Oblast	1686.2	Omsk	Oblast	4363
Buryat	Republic	1685.9	Orenburg	Oblast	4345.8
Chechen	Republic	346.4	Oryol	Oblast	1594.1
Chelyabinsk	Oblast	7995.8	Penza	Oblast	1706.1
Chita	Oblast	1859.4	Perm	Oblast	8058.3
Chukotsky	Autonomous Okrug	11325.8	Permyakia	Autonomous Okrug	4305.3
Chuvash	Republic	1741.8	Primorsky	Krai	1052.1
Dagestan	Republic	2326.3	Pskov	Oblast	9707.2
Evenkiysky	Autonomous Okrug	141.8	Rostov	Oblast	6366.7
Ingushetia	Republic	167.4	Ryazan	Oblast	2301.8
Irkutsk	Oblast	5999	Saint Petersburg	Federal City	15122.6
Ivanovo	Oblast	1250.9	Sakha	Republic	4526.4
Jewish	Autonomous Oblast	298.3	Sakhalin	Oblast	–
Kabardino-Balkar	Republic	938.3	Samara	Oblast	9541
Kaliningrad	Oblast	1783.5	Saratov	Oblast	4557.5
Kalmykia	Republic	4770.8	Smolensk	Oblast	1794.7
Kaluga	Oblast	1852.9	Stavropol	Krai	3823.1
Kamchatka	Krai	1016.8	Sverdlovsk	Oblast	11133.6
Karachayevo-Cherkessia	Republic	412.5	Taimyrsky (Dolgano-Nenetsky)	Autonomous Okrug	36269
Karelia	Republic	1668.1	Tambov	Oblast	1765.6
Kemerovo	Oblast	5948.7	Tatarstan	Republic	11075
Khabarovsk	Krai	4253.7	Tomsk	Oblast	3600.3
Khakassia	Republic	997.4	Tula	Oblast	2683.8
Khanty-Mansi	Autonomous Okrug	26409.8	Tuva	Republic	166.6
Kirov	Oblast	2165.5	Tver	Oblast	2573
Komi	Republic	3941.4	Tyumen	Oblast	2145.2
Koryaksky	Autonomous Okrug	150.6	Udmurtia	Republic	3393.1
Kostroma	Oblast	1144.2	Ulyanovsk	Oblast	2025
Krasnodar	Krai	9573.7	Ust-Ordynsky Buryatsky	Autonomous Okrug	145.4
Krasnoyarsk	Krai	9548.8	Vladimir	Oblast	2326.3
Kurgan	Oblast	1386.9	Volgograd	Oblast	4770.8
Kursk	Oblast	2066.6	Vologda	Oblast	3962.7
Leningrad	Oblast	4595.1	Voronezh	Oblast	3646.4
Lipetsk	Oblast	3406.5	Yamalo-Nenets	Autonomous Okrug	11325.8
Magadan	Oblast	797.6	Yaroslavl	Oblast	3626.9
Mari El	Republic	853.2			

Notes: In 2003, Russia had 49 oblasts (provinces), 21 republics, 6 krais (territories), 10 okrugs (autonomous districts), 1 autonomous oblast, and 2 federal cities (Moscow and St. Petersberg).

B The Location of Products and Ports

We show that the location of Russian exporters can neither be accounted for by the location of export commodities nor the location of borders and ports.

Russia's major manufacturing industries are: all forms of machine building from rolling mills to high-performance aircraft and space vehicles; defense industries including radar, missile production, and advanced electronic components, shipbuilding; road and rail transportation equipment; communications equipment; agricultural machinery, tractors, and construction equipment; electric power generating and transmitting equipment; medical and scientific instruments; consumer durables, textiles, foodstuffs, and handicrafts.

Russia's largest export commodities are: petroleum products, wood and wood products, metals, chemicals, and a wide variety of civilian and military manufactures. Products such as petroleum, wood, metals, and chemicals need to be processed to become manufactured goods. Therefore it is possible that the location of exports is the same as the location of the refineries and processing plants for these goods.

Figure 1 shows that though many exporters are located in the same region as a major port, there are regions that are not close to a major port in the top quintile of the number of exporting firms. The largest ports are Azov (Rostov, Black Sea), Kaliningrad (Kaliningrad, Baltic Sea), Nakhodka and Vostochny (Primorsky, Sea of Japan, largest), Novorossiysk (Krasnordar, Black Sea, largest), Primorsk (Leningrad, Baltic Sea, largest, lots of oil), and Saint Petersburg (Saint Petersburg, Baltic Sea). Cassey (2010) documents that access to water is an important predictor of U.S. state exports.

C Exports in the Context of Output

If external geography played no role in the location of exporters, the pattern of region-country aggregate exports (X_{ij}) would be identical to the pattern of regional production (Y_i) with some randomness. In this case, the destination of Russian sales would not matter for the location of Russian exporters. To show that this does not hold, we conduct two simple tests. The first test is to run the following regression:

$$\log X_{ij} = \underset{(0.386)}{-5.395} + \underset{(0.046)}{0.433^*} \log Y_i + \varepsilon_{ij} \tag{11}$$

$$N = 3028, \quad R^2 = 0.029, \quad RMSE = 2.621$$

The index i runs over the set of Russia's regions and the index j runs over the set of countries in the world. Standard errors are robust and a * indicates the estimated coefficient is significantly different from zero with 99% confidence. The extremely low explanatory power as given by the R^2 indicates that the pattern of production in Russia does not account for the pattern of exports in the data.

The second test is to compare the ratio of exports from each Russian region to the ratio of GDP from each region to Russia. We modify the familiar concept of location quotient to put Russian exports by region into the context of overall economic activity,

$$LQ_i = \frac{X_i}{X} \Big/ \frac{Y_i}{Y}.$$

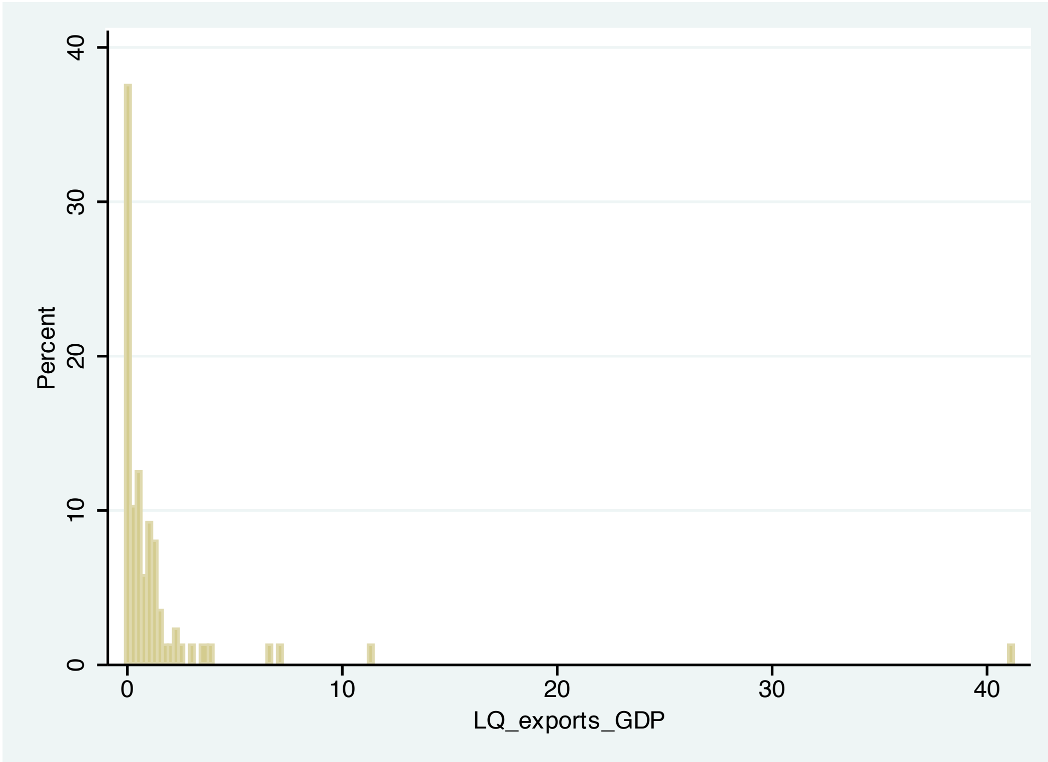

Figure 5: LQ Histogram

If the LQ is greater than 1 then the region's export share to the world is larger than it's share of GDP. This indicates the region is relatively specialized in exporting in comparison to overall economic activity. The strength of this approach is that it controls for the geography of economic activity within Russia,

The average LQ_i is 1.454 with standard deviation 0.489. But though the average LQ_i is *not* significantly different from one, the regions with the largest LQ_i are several times the standard deviation. Figure 5 shows the histogram of LQ_i. Though most region's LQ_i is around 1, there are many that are in the right tail of figure 5. Thus there are regions in Russia that are heavily concentrated in exporting compared to overall output and regions that do not export anything at all.

Because we only consider manufacturing activity, we repeat the proceeding exercise by scaling the regional GDP data by the share that is from industry. The results (not reported) are not qualitatively different from before. Therefore, we have documented that Russian exporters are not simply located in the geographic pattern of industrial economic activity.

D Robustness

One feature of the Russian export data is the high frequency of zeros. There are 89 regions in Russia and we have 2003 GDP data (IMF 2006) and distance for 179 countries. Therefore, there are 15,931 possible observations. Of these, only 3034 have positive exports, or 19% (our regressions use only 3028 observations because of missing regional GDP information). Santos Silva and Tenreyro (2006) show that (2) with OLS can bias estimates when there are many zeros in the data. We follow them and use the poisson quasi-maximum likelihood estimator.

$$\frac{X_{ij}}{Y_iY_j} = \exp\left(\underset{(1.187)}{-18.861^*} \times \log D_{ij}^{\underset{(0.149)}{-1.041^*}} + \sum_{i=2}^{89} \kappa_i S_i + \sum_{j=2}^{179} \delta_j T_j \right) \times \varepsilon_{ij}.$$

$$N = 15752, \quad AIC = 534.00$$

$$\frac{X_{ij}}{Y_iY_j} = \exp\left(\underset{(1.162)}{-14.784^*} \times \log D_{ij}^{\underset{(0.119)}{-.801^*}} \times \log W_{ij}^{\underset{(0.027)}{.116\ ^*}} + \sum_{i=2}^{89} \kappa_i S_i + \sum_{j=2}^{179} \delta_j T_j \right) \times \varepsilon_{ij}.$$

$$N = 3028, \quad AIC = 424.00$$

Though the estimates for the regression with the agglomeration term change quantitatively, the are the same qualitatively. The agglomeration term is economically and statistically significant. Importantly, the model with the agglomeration term has a lower Akaike Information Criterion than the model without the term, indicating the model with agglomeration is preferred. However, region-country observations of zero exports also have zero weight for those exports. Santos Silva and Tenreyro do not consider the model where zeros occur on both the left and right hand side of the regression.