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EXPORTS AND LOGISTICS

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Do better trade logistics reduce trade costs, raising a country's exports? Yes, but the magnitude of the effect depends on country size. Applying a new gravity model to a comprehensive logistics index, we find that an average-sized country would raise exports by about 46% after a one-standard deviation improvement in logistics. Most countries are much smaller than average however, so the typical effect is only 6%. This difference is chiefly due to multilateral resistance, which stresses that bilateral trade costs *relative to* multilateral trade costs matter for bilateral exports. Our method also distinguishes between the effects of logistics on the intensive margin (exports per firm) and the extensive margin (the number of exporting firms) of trade.

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1. INTRODUCTION

International trade costs are equivalent to a 74 per cent *ad valorem* tariff for a typical product traded between industrialized countries (Anderson and van Wincoop, 2004). They are higher between developing countries. For example, freight costs in developing countries are on average 70 per cent higher than in developed countries (UNCTAD, 2003). Costs include distribution expenses, border-related barriers and transport charges. Despite improvements in technology, trade costs associated with distance are still large (Brun, Carrere, Guillaumont & de Melo, 2005). Uncertainty over the time goods take to ship is also costly to exporters (Hummels, 2001).

Buys, Deichman & Wheeler (2006) calculate that their programme of road network expansion in Africa would increase trade by $250 billion over 15 years at a cost of $20 billion plus $1 billion per year. This might make a compelling case for upgrades, but roads are not everything. Freight costs are also affected by the broader infrastructure – including rail, port and communication facilities. Uncertainty interacts with the transport infrastructure – tarred roads are less likely to be flooded than gravel ones after a storm – but also arises due to a lack of transparency and reliability in customs procedures. Through the transport cost channel, a number of studies have associated the quality of infrastructure with trade volumes (Clarke et al, 2004; Limão & Venables, 2001; Wilson, Mann & Otsuki, 2005; Nordås & Piermartini, 2004).

This paper uses an index of logistics quality developed by the World Bank to investigate the relationships between logistics and bilateral exports from developing countries. This new index draws on a wide range of criteria: in addition to physical infrastructure, it incorporates measures of expertise and of customs clearance reliability. It therefore captures a broad range of trade costs, both pecuniary and those associated with uncertainty. An additional advantage is that the data come from a single source and are based on detailed evaluations provided by logistics professionals (Arvis, Muster, Panzer, Ojala & Naula, 2007).

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We show that standard gravity approaches would produce a four-fold exaggeration of the typical impact of logistics on exports. The exaggeration is even bigger for small countries. Our novel gravity modelling approach simultaneously accounts for multilateral resistance and selection issues associated with firm heterogeneity. In so doing we incorporate insights from two recent strands of the empirical trade literature. First, Anderson & van Wincoop (2003) show that it is not just bilateral trade costs, but those costs relative to multilateral trade costs that are relevant for predicting bilateral trade flows. Anderson & van Wincoop call the latter *Multilateral Resistance*. Omitting controls for multilateral resistance (MR) can lead to biased coefficient estimates. More importantly, it can lead to grossly misleading comparative static estimates of the impact of trade barriers on trade flows: MR typically dampens bilateral trade elasticities. Behar (2009) shows that trade elasticities are approximately proportional to country size because bigger countries are less affected by MR.

Second, Helpman, Melitz & Rubinstein (2008) develop a method to account for the consequences of heterogeneous firm productivity in gravity models. Firm heterogeneity gives rise to two margins of adjustment to changes in trade barriers: the intensive margin, which captures exports per firm, and the extensive margin, which captures the number of exporting firms. If fixed trade costs are sufficiently high, no firms in a given country may export to a particular destination. This gives rise to zeros in aggregate trade data. Failure to account for these issues can affect estimation of the gravity model parameters and comparative static effects.

Behar & Nelson (2009) develop a model which accommodates both MR and firm heterogeneity. They demonstrate the importance of these effects for comparative statics when trade costs are captured by bilateral distance. In this paper, we adapt that approach to the case of logistics. Unlike distance, logistics might not be exogenous, so we take potential endogeneity seriously. Further, unlike bilateral distance, the logistics index is a country-specific variable which precludes the use of fixed effects to control for MR in estimation. Instead, we proxy MR terms using Baier and Bergstrand's (2009) method. Our approach allows us to implement this method together with Helpman, Melitz & Rubinstein's procedure to account for firm heterogeneity.

Section 2 provides an overview of the existing literature on infrastructure and international trade before explaining the importance of MR and the selection issues associated with firm heterogeneity. Section 3 describes the data. Section 4 formalizes our gravity modelling framework and illuminates the reasons for the gross exaggeration the benchmark linear specification would produce. To introduce the controls for MR and isolate the important role it plays in comparative statics, we start with a model in which firms have homogeneous productivities. Thereafter, we present the heterogeneous firm model and its implications. Section 5 discusses estimation issues, including endogeneity and the omitted variable biases caused by ignoring MR or firm heterogeneity. While the homogeneous goods model can be estimated by OLS, as in Baier & Bergstrand (2009), we incorporate Helpman, Melitz and Rubinstein's two-step procedure used to estimate the heterogeneous firm model. In section 6, the benchmark linear specification suggests a one standard deviation improvement in logistics quality, which would put Rwanda on a par with Nigeria, raises exports 31%. We use our homogeneous firms model to model the impact of MR on estimation and to suggest that potential endogeneity is not biasing the logistics coefficient in any particular direction.

Consistent with HMR and Behar & Nelson, accounting for firm heterogeneity using the two-stage procedure produces bigger country-level comparative statics for an average-size country than does the homogeneous goods model estimated by OLS. Our simulations in section 7 indicate that a one standard deviation rise in the index would raise exports by about 46% for an average-size country. However, the impact of MR varies by country size and most countries are much smaller than average. Therefore, we compute the elasticity for each of our 86 exporters. For example, because Rwanda is small, its trade response of 0.3% would be less than 1% the response implied by the benchmark specification. Averaging over all exporters, the typical effect is about 6%, which the benchmark would exaggerate four-fold. In section 8, we introduce additional specifications. One shows that logistics improvements can be more beneficial for poor landlocked countries. Another set of specifications suggests that an exporter's neighbors' logistics can help boost exports. Section 9 recollects that small countries have much smaller trade responses than the average but cautions against interpreting these results as a weak case for logistics upgrades in those countries.

2. LITERATURE

2.1. Studies on logistics

Lower transport costs have been shown to increase trade volumes. Limão & Venables (2001) map information on road, rail and phone infrastructure to shipping cost information garnered from freight forwarders. They calculate that variation in infrastructure accounts for 40 per cent of variation in transport costs. In a gravity framework, they find that a country improving its infrastructure from the median to the 75th percentile would increase its trade 68 per cent. Limão & Venables find the median landlocked country trades much less than a coastal country. This may be because the incidence of transport costs falls on landlocked countries (Amjadi & Yeats, 1995).[5] Limão & Venables calculate that the transport cost for the median landlocked country is 55 per cent higher than for the median coastal country.

Similarly, Clarke et al (2004) find port facilities and general infrastructure contribute to ocean freight costs. These costs, which are based on containerization, the regulatory environment, seaport infrastructure and other variables also materially impact trade. Nordås & Piermartini (2004) adopt a similar approach to Limão & Venables but use more infrastructure measures. They have separate specifications for a number of indicators – airports, roads, telephone lines, port efficiency and the median port clearance time – which are estimated separately. They find all components are significant determinants of trade, with port efficiency being the most influential.

Moving beyond infrastructure, Hummels (2001) finds that improvements in customs clearance sufficient to reduce waiting times by a day would be equivalent to a 0.8 per cent reduction in ad valorem tariffs. Djankov et al (2006) calculate that a delay of one day is equivalent to an additional bilateral distance of about 70km. They suggest the delay cost is higher for developing countries because of the nature of their exports.

Wilson et al (2005) define and evaluate four measures of trade facilitation: port facilities, customs handling, the regulatory environment and the availability of service sector infrastructure. To do this, they combine information from three sources to study manufacturing exports from 75 countries. They find that improvements in all four measures would have material impacts on both exports and imports, with a bigger impact on exports.

2.2. Methodological concepts

Our approach accounts for two important insights provided by the recent gravity literature on trade flow estimation. In particular, our estimation and comparative static exercises account for both MR and firm heterogeneity.

[5] Gallup, Sachs & Mellinger (1999) have suggested the landlocked are particularly vulnerable because cross-national infrastructure projects are difficult to implement, but it's not just about infrastructure: Gallup et al also suggest coastal neighbours may have military or economic incentives to impose costs on the landlocked deliberately. As a result, the "Almaty Programme" is aimed at relieving some of the difficulties faced by landlocked countries. Goals include recognizing freedom of transit, developing transport infrastructure and fostering transnational co-operation (Arvis, Raballiland & Marteau, 2007).

2.2.1. Multilateral resistance

Anderson and van Wincoop (2003) show that it is essential to account for the general equilibrium effects of changes in trade costs if comparative statics are to be correct. The effect works through the price indices that enter the bilateral gravity equation. Since these indices aggregate the trade costs incurred in consuming a given bundle of traded goods, Anderson and van Wincoop (2003) refer to them as indices of multilateral resistance (MR). The effects of MR are as follows. The bilateral trade flow between two countries depends not only on the bilateral trade barrier between them, but the severity of this barrier relative to those confronted when the two countries trade with others (including domestic trade). It follows that the effect of a change in a trade barrier must account for these potentially significant 'third party' effects. The impact on Brazil's exports to Peru of signing a trade agreement depends also on whether other countries are party to that agreement. Were the agreement bilateral only, a reduction in the Brazil-Peru trade barrier would stimulate Brazilian exports to Peru, potentially reducing exports to third parties (eg Uruguay) and to itself. Were the agreement to include Uruguay, the relevant cost for Brazilian exports to Peru is the new cost of exporting to Peru relative to that of exporting to Uruguay; in relative terms, these costs have not changed. In this case, the only change in relative trade costs is that between domestic and international trade, with the costs associated with the latter falling relative to the former.

These effects are shown to be quantitatively important by Anderson and van Wincoop in explaining the so-called US-Canada 'border puzzle' of McCallum (1995). Behar and Nelson (2009) show that the effects of MR are large for changes in trade costs that are multilateral in nature. Changes in a given country's logistics quality share some of this multilateral characteristic: if Kenya were to achieve an improvement in its logistics, its relative trade barrier across all export destinations would be affected, and our comparative statics on exports to a particular destination must reflect this. Put differently, since the gravity equation for bilateral trade flows is derived from a general equilibrium system, any statement about the likely impact of this change on bilateral trade flows must take general equilibrium effects, through MR, into account. Without doing so, comparative statics exercises will generally overestimate the true magnitude of the response of bilateral trade flows to a change in trade costs.

Furthermore, larger countries typically trade a larger fraction of their output domestically for a given international trade cost. For large countries, a smaller proportion of their total (i.e. domestic plus international) trade is affected by changes in international trade costs with all destinations, which are captured by changes in MR. As a result, MR effects are less important and hence trade elasticities are greater for larger countries.

There are a number of empirical approaches to controlling for MR in estimation. First, since MR terms are country-specific, they can be controlled for by including country fixed effects. This is not appropriate for our purposes as we want to identify the effect of country-specific logistics quality. Second, some attempts have been made to control for MR by using price data to construct the appropriate price indices. Data limitations are among the problems with this method. As noted in Feenstra (2004), published price indices are typically stated relative to an arbitrary base period, making comparison of levels impossible. Furthermore, they tend to include too many non-tradeable goods and thus fail to capture the additional costs embedded in internationally traded goods (Anderson & van Wincoop, 2004). Third, Anderson & van Wincoop (2003) propose solving for a system of price indices together with the gravity equation, but this involves a potentially problematic customized non-linear program.[6] Fourth, Baier and Bergstrand (2009) introduce a method by which the MR terms are approximated using a first-order Taylor expansion, yielding a log-linear expression for MR which contains exogenous variables only. These approximated MR terms can then be included in the estimating equation. This approach

[6]This method is especially demanding when considering about 100 countries and allowing for asymmetries in trade frictions. Bergstrand, Egger & Larch (2007) have shown that, because of asymmetries, the system solution can yield complex numbers. It may be for this reason that it has not been widely adopted by empirical researchers.

has the advantage of yielding tractable comparative statics; in particular, the role of country size in determining the appropriate comparative static effect is made explicit, while Baier and Bergstrand show that the approximation error associated with this method is small for the majority of country pairs.

2.2.2. Firm heterogeneity

Models of monopolistic competition with firms of heterogeneous productivity predict selection into export markets in the presence of fixed costs of trade. The reason is that the least productive firms do not generate profits sufficient to cover the fixed costs incurred, preventing entry into overseas markets. As illustrated by HMR, this has at least two further implications. First, the impact of a change in a trade barrier affects both the amount a given firm exports, the intensive margin, and the number of firms that export, the extensive margin. The latter is a *firm* selection effect. 'Traditional' gravity equations conflate these two effects, whereas HMR's method allows their decomposition. Second, for fixed costs sufficiently high, no firms in a given country may find it profitable to export to a particular destination. This is offered as an explanation of the 'zeros' observed in bilateral trade data: many country-pairs do not appear to trade at all. This is a *country* selection effect, and it induces bias in traditional gravity estimates.

HMR propose a two stage estimation procedure to construct controls for these effects. In a procedure to be described below, we use the elements of their approach that allow us to control for the effects of firm heterogeneity and simultaneously account for MR using the Baier & Bergstrand (2009) approximation introduced above.

3. DATA

The logistics performance index is sourced from the World Bank[7] and is constructed on a scale from 1-5. The aggregate index is calculated by the World Bank using a Principal Components Analysis of the six different sub-indicators. The indicators are listed below together with their weights in the index.[8]

1. Efficiency of the clearance process by customs and other border agencies (0.18);
2. Transport and information technology infrastructure (0.15);
3. Local logistics industry competence (0.16);
4. Ease and affordability of international shipments (0.20);
5. The facility to track and trace shipments (0.16);
6. The timeliness with which shipments reach their destination (0.15).

Efficiency of the clearance process by customs and other border agencies, the ease and affordability of arranging international shipments, the ability to track and trace those shipments as well as the speed with which they reach their destinations are directly relevant to international trade. Transport and IT infrastructure are relevant to all trade, whether international or domestic, as is the competence of the local logistics industry.

Further details of the construction of each indicator are available in Arvis, Mustra et al (2007). In summary, the index is based on more than 5,000 country evaluations by logistics professionals. The

[7] http://go.worldbank.org/88X6PU5GV0

[8] The weights that are used are not reported by the World Bank but can be backed out. For each country we have $LPI_i = C_i w_i$ where LPI_i is the total LPI score, C_i is a 6x1 vector of the six component scores and w_i is a 6x1 vector of the weights. We can then use six different country LPI scores and components to form a matrix equation $w_i = (C_i^T)^{-1} LPI_i$, which solves for the weights. We do this for a number of different sets of countries to ensure that the weights we calculate are unaffected by rounding errors. Originally, data was also collected on a seventh component: domestic logistics costs. This component was found to be uncorrelated with the others and was consequently dropped by the World Bank.

perceptions-based measure is corroborated with a variety of qualitative and quantitative indicators. For example, Arvis, Mustra et al (2007) calculate that, on average, a one-point rise in the overall logistics index corresponds to exports taking three more days to travel from the warehouse to port. Unlike other studies, for example Wilson et al (2005), the components of the index are drawn from the same source. In our sample, the lowest value (1.77) is for Rwanda and the highest is for Singapore (4.19). Table 1 shows that the mean is 2.78. Richer countries tend to have higher logistics quality but there is some overlap between income classification, with some low-income countries having better logistics than middle-income countries.

Our sample consists of 86 exporters, constituting low- and middle-income countries only, and 111 importers, which includes all countries, based on the availability of logistics data and possible instruments and controls. We have excluded countries classified as islands or which do not have neighbors in the data because we want to investigate neighborhood logistics. We use merchandise exports data for 2005, using the IMF Direction of Trade Statistics. Out of a possible 9,460, we have 6,322 positive cross-border trade flows, 2,330 recorded as zeros and 808 instances of missing values. We therefore need to account for potential sample selection issues in our model and econometric methodology.

We use 2005 GDP measured in constant (2000) US Dollars from the World Development Indicators. As will become clear, each country's GDP share is an important component of our analysis. We calculate each country's share of world GDP by dividing its GDP by the WDI measure of world GDP. As will be explained, we restrict ourselves to those exporters defined by the World Bank as low- and middle-income, so the mean share of world GDP is 0.17% and Brazil is the biggest country in our sample with a share of 1.84%. We have 86 exporters and will see that the regression coefficient is the coefficient for an average-sized exporter, where the denominator for the average GDP share is total GDP of all exporters in the sample. The average GDP as a share of the sample is $1.16\% \approx \frac{1}{86}$.

The measure of bilateral distance that we use captures the internal distance in a country, accounts for the distance from a number of major cities and is constructed by CEPII.[9] Border data are also sourced from CEPII. This information is used to construct unweighted averages of logistics in a country's neighbors. Our control variables, including dummies for whether or not two countries share a common language[10], a common colonizer or were once the same country, as well as a dummy for a land-locked country, are sourced from CEPII. Additional variables for identification as fixed export costs or instruments are taken from the World Bank *Doing Business* database. These data include the number of procedures needed to start a business, the number of days it takes to start a business and the cost of registering to start a new business in a country. We also considered data on the number of documents required to export or to import goods.

4. GRAVITY MODELLING FRAMEWORK

We model the relationship between exports and logistics using a gravity equation. This equation has a long and successful history in explaining bilateral trade patterns, with much of the explanatory power coming from the two countries' GDPs and the distance between them. Theory has subsequently provided grounding for the empirical success of the gravity model (Anderson 1979, Bergstrand 1985). The importance of multilateral resistance was highlighted in Anderson & van Wincoop (2003) and that of firm heterogeneity by Helpman, Melitz & Rubinstein (2008). We introduce MR in a homogeneous firms model before incorporating it in a heterogeneous firms model. The theoretical background and derivations are in the appendix.

[9] The distance measure used is distw from http://www.cepii.fr/anglaisgraph/bdd/distances.htm

[10] We construct a dummy that is equal to one if two countries share either a common official or common ethnic language.

4.1. Homogeneous firms model

The Anderson & van Wincoop (2003) gravity equation for exports from j to i is (see Appendix A.1):

$$M_{ij} = \frac{Y_i Y_j}{Y}\left(\frac{t_{ij}}{P_i P_j}\right)^{1-\sigma}, \tag{1}$$

where bilateral trade is a function not only of bilateral frictions (t_{ij}) but multilateral price indices (P_i & P_j) known as multilateral resistance. $\sigma > 1$ is the elasticity of substitution while Y_i, Y_j and Y are GDP in the importer, exporter and world. The Baier & Bergstrand (2009) approximation for the price indices produces a log linear function of trade frictions in all other countries, weighted by their GDPs. This approximation allows us to specify the log of exports from country j to country i as

$$\begin{aligned} m_{ij} &= y_i + y_j - y - (\sigma-1)\ln t_{ij} + (\sigma-1)\ln(P_i P_j) && \text{(2a)} \\ &= y_i + y_j - y - (\sigma-1)\ln t_{ij} && \text{(2b)} \\ &\quad + \sum_h s_h(\sigma-1)\ln t_{ih} + \sum_k s_k(\sigma-1)\ln t_{kj} - \sum_k\sum_h s_k s_h(\sigma-1)\ln t_{kh}. \end{aligned}$$

Trade is bigger for bigger country pairs and lower for higher bilateral trade frictions t_{ij}. The summation terms approximate MR. The first term is importer i's multilateral resistance, which sums bilateral frictions over all exporters to i and acts to make imports from j relatively more attractive. The second term is exporter j's multilateral resistance, which sums over all export destinations from exporter j and acts to make exports to i more attractive. The third term measures average world trade barriers, which sums bilateral frictions across all country pairs and acts to make international trade between all country pairs including pair (i, j) less attractive relative to internal trade.

We specify cross-border trade frictions in terms of bilateral distance and in terms of the quality of logistics in the exporting country: $(\sigma-1)\ln t_{ij} = \gamma d_{ij} - \lambda L_j$, where we see that a higher logistics quality reduces t_{ij}.When logistics quality improves, the partial equilibrium effect, which ignores MR, is given by $\frac{\partial m_{ij}}{\partial L_j} = \lambda$. However, as shown in Behar (2009), the full general equilibrium effect is given by[11]

$$\begin{aligned} \left.\frac{\partial m_{ij}}{\partial L_j}\right|_{\text{homog.}} &= \lambda\left\{1 + s_j(1-s_j) - s_j - (1-s_j)\right\} && \text{(3a)} \\ &= \lambda s_j(1-s_j) && \text{(3b)} \\ &\approx s_j\lambda. && \text{(3c)} \end{aligned}$$

The first term in the {} brackets (1) gives the partial equilibrium effect in the absence of MR. The third term is the effect operating through the importer's multilateral resistance, which falls by the exporter's GDP share, dampening the partial equilibrium effect. The fourth term is the exporter's multilateral resistance, which falls across all export destinations relative to domestic trade. The proportion of j's export demand this covers is $1 - s_j$. The second term is the effect operating through "world resistance", which captures how costly international trade is relative to domestic trade for all countries. It is also the net general equilibrium effect after one allows for terms to cancel. It illustrates the diversion of exports away from domestic trade and towards international trade as international trade costs fall. Simplifying (3a) clearly shows that the net comparative static effect is not λ, but something *much* smaller. The comparative static effect (3c) is increasing in country size. This is consistent with Anderson & van Wincoop (2003), who found that smaller countries experience smaller comparative static effects because they are more affected by MR. As discussed in section 2.2.1, the reason for this is that smaller

[11] This assumes logistics quality improvements affect only cross-border trade costs. In an Anderson & van Wincoop (2003) framework, an equal improvement in internal logistics would have no effect on relative prices and hence no effect on exports. The description of the logistics variable suggests that many components are directly relevant to cross-border trade and it is therefore reasonable to propose that logistics would have a disproportionate effect on cross-border costs.

countries consume a smaller proportion of their produce domestically and export a larger proportion of their products abroad. More of their trade is international trade, so more is subject to international trade costs, so MR has more of an effect.

4.1.1. Implications for estimation

For the purposes of estimation, we assume that all countries have equal shares such that $s_k = \frac{1}{n}$. The gravity equation becomes

$$m_{ij} = \psi + \beta \left(y_i + y_j\right) - \gamma \left(d_{ij} - MR_{ij}^{dist}\right) + \frac{\lambda}{n} \left(L_i + L_j\right), \tag{4}$$

where ψ is a constant, $MR_{ij}^{dist} = -\frac{1}{n^2} \sum_k \sum_l d_{lk} + \frac{1}{n} \sum_k d_{ik} + \frac{1}{n} \sum_l d_{lj}$ (cf Baier & Bergstrand (2007)) and country-specific terms can be collected to yield the simpler expression for logistics (Behar, 2009). The above specification allows one to interpret the coefficient on $(L_i + L_j)$ as the effect of an improvement in logistics on bilateral trade for an average-size country with $s_k = \frac{1}{n}$. Thus, the comparative static effect for an average-size country is

$$\overline{\left.\frac{\partial m_{ij}}{\partial L_j}\right|_{\text{homog.}}} \approx \frac{\lambda}{n}. \tag{5}$$

4.2. Heterogeneous firms model

Some firms are more productive than others. Only some are sufficiently productive to export to a particular destination.[12] As argued in Helpman, Melitz & Rubinstein (2008), neglecting firm heterogeneity means we do not account for firm entry into new export markets after a reduction in trade frictions. Independent of MR, they argue that standard parameter estimates may not be a good indicator of a country-level response because it conflates effects at the intensive margin (firms exporting more) and extensive margin (firms deciding to export). This may lead to biased estimates of the trade friction parameter itself and of the country-level comparative static.

Behar & Nelson (2009) develop a model accommodating both MR and firm-heterogeneity in productivity. Here, we follow that framework to produce a heterogeneous analogue of (1) (see Appendix A.2)

$$M_{ij} = \frac{Y_i Y_j}{Y} \left(\frac{t_{ij}}{P_i P_j}\right)^{1-\sigma} V_{ij}. \tag{6}$$

V_{ij} is the proportion of firms exporting from j to i. The heterogeneous firm analogue of (2a) becomes

$$m_{ij} = y_i + y_j - y - (\sigma - 1) \ln t_{ij} + w_{ij} + (\sigma - 1) \ln(P_i P_j). \tag{7}$$

$(\sigma - 1) \ln(P_i P_j)$ is as before[13] while w_{ij} is a term capturing the *firm* selection effect, which we will show is related to the control for the *country* selection effect.

4.2.1. Estimation with heterogeneity

Only those firms productive enough to cover the fixed cost of exporting from j to i will export, which econometrically requires the construction of the variable w_{ij} to control for the extensive margin. HMR argue w_{ij} is a monotonic function of a latent variable z_{ij}, which is the log of the ratio of the variable profit in the most productive firm in j to the fixed cost of exporting to i. While we do not observe this

[12] There is a growing consensus that causality runs from productivity to exports, not the other way around. See the review in Bernard, Jensen, Redding & Schott (2007).

[13] Despite the possibility of firm selection, we continue to assume that price indices are a function of all individual goods, as in the homogeneous case. This differs from Behar & Nelson, who make the price index a function only of those goods actually available in that country yet still obtain equation (6). Our simplification is extremely useful because we do not use fixed effects to estimate the price terms in either the first or second stage. It also permits an intuitive and straightforward closed form solution.

variable, we do observe bilateral trade flows, which only occur if the most productive firm is sufficiently productive to make exports profitable, or $z_{ij} > 0$. The probability of exporting by the most productive firm, together with a distributional assumption on firm productivities, allows us to construct w_{ij} from z_{ij}. As in Behar & Nelson,

$$z_{ij} = y_i + y_j - y - (\sigma - 1)\ln t_{ij} + (\sigma - 1)\ln(P_i P_j) + \kappa f_{ij} \tag{8}$$

is a gravity equation for the extensive margin. f_{ij} is the fixed cost of exporting from j to i. (8) explicitly shows the latent variable is a function of multilateral as well as bilateral frictions. In other words, MR affects both the intensive and extensive margins. To write the analogue of (4), we substitute for $\ln t_{ij}$ and $\ln(P_i P_j)$ as before. As is common in this literature, we assume firm productivity ($\frac{1}{a}$) is Pareto distributed.[14] Then $w_{ij}(z_{ij}) = \ln\left(e^{\delta z_{ij}} - 1\right)$, where $\delta \equiv \frac{\mu - \sigma + 1}{\sigma - 1} > 0$, in which μ is the shape parameter of the Pareto distribution. Then

$$m_{ij} = \psi + \beta_y (y_i + y_j) - \gamma\left(d_{ij} - MR_{ij}^{dist}\right) + \frac{\lambda}{n}(L_i + L_j) + \ln\left(e^{\delta \hat{x}_{ij}} - 1\right) + \beta_\eta \hat{\eta}_{ij}. \tag{9}$$

$\hat{\eta}_{ij}$ is the inverse Mills Ratio, which controls for country selection. As will be discussed in the estimation section, $\hat{x}_{ij}$ is a predicted value for z_{ij} constructed after estimating a first stage probit regression for the probability that country j exports to country i.

4.2.2. Comparative statics with heterogeneity

Comparative statics must now take into account three effects. In particular, a change in logistics quality must account for

1. the effect at the intensive margin, $\frac{-(\sigma-1)\partial \ln t_{ij}}{\partial L_j} = \lambda$;
2. the MR effect occurring at the intensive margin, $\frac{(\sigma-1)\partial \ln P_i P_j}{\partial L_j} = -\lambda(1 - s_j + s_j^2)$;
3. the effect at the extensive margin, which also has bilateral and multilateral components, where $\frac{\partial z_{ij}}{\partial L_j} = \lambda s_j (1 - s_j)$ and, by the chain rule, $\frac{\partial w_{ij}}{\partial L_j} = \left(\frac{\delta e^{\delta \hat{x}_{ij}}}{e^{\delta \hat{x}_{ij}} - 1}\right) \lambda s_j (1 - s_j)$.

As in the homogeneous case, combining (1) and (2) gives $\lambda s_j (1 - s_j)$ (cf. equation (3)). Adding the third effect at the extensive margin yields

$$\left.\frac{\partial m_{ij}}{\partial L_j}\right|_{\text{hetero.}} = \lambda\left[s_j (1 - s_j)\right]\left[1 + \frac{\delta e^{\delta \hat{x}_{ij}}}{e^{\delta \hat{x}_{ij}} - 1}\right]. \tag{10}$$

The gravity parameter λ is the effect at the intensive margin, not accounting for MR. The first square bracket is the adjustment for MR. The second square bracket, which exceeds unity, is the amplification brought about by allowing for the effect at the extensive margin. Note that ignoring this term gives the intensive margin, provided we have controlled for w_{ij} in estimation in our heterogeneous firm model. If we have not controlled for firm selection and we estimate a homogeneous firms model, then the firm and country-level response is the same, as in this case there is no firm entry or exit into overseas markets and all firms experience the same trade elasticity.

In the heterogeneous model, the $\frac{\lambda}{n}$ coefficient on $(L_i + L_j)$ still forms the approximate intensive margin change for an average-size country while $\frac{\lambda}{n} \frac{\delta e^{\delta \hat{x}_{ij}}}{e^{\delta \hat{x}_{ij}} - 1}$ gives the approximate extensive margin change for an average-size country. The bilateral country-level effect is therefore

$$\overline{\left.\frac{\partial m_{ij}}{\partial L_j}\right|_{\text{hetero.}}} \approx \frac{\lambda}{n}\left[1 + \frac{\delta e^{\delta \hat{x}_{ij}}}{e^{\delta \hat{x}_{ij}} - 1}\right]. \tag{11}$$

[14] Then $G(a) = \frac{a^\mu - a_L^\mu}{a_H^\mu - a_L^\mu}$, for $a \in [a_L, a_H]$, where μ is the shape parameter of the Pareto distribution.

5. ESTIMATION

To place our model in a stochastic framework, we allow for measurement error in the reporting/recording of trade flows and unobserved trade costs. A necessary condition for consistent estimates is that the error term is independently and identically distributed (IID). This section will discuss potential reasons why the IID assumption might not hold. It also discusses the dropping of high-income exporters from our sample.

Endogeneity bias The IID assumption rules out reverse causation. There is ambiguity regarding the relationship between logistics and trade. Our theoretical framework describes a unidirectional impact of improved logistics on exports. However, it may be that higher trade volumes stimulate the construction of new infrastructure and the introduction of more efficient clearance technologies: the marginal value of investments in trade facilitating measures may be higher if exports are high, while some aspects of the logistics technology are subject to scale economies and thus only worthwhile at very high volume. This could cause an upward bias in the estimated coefficient. On the other hand, high trade volumes may increase the strain on the system, leading to queues at the border and longer customs processing times (Djankov et al, 2006), and causing downward bias in the estimates. Restricting the coefficients could mitigate endogeneity because the importer's logistics should not be affected by one exporter's exports. Nonetheless, we include instrumental variables (IV) specifications.

Omitted multilateral resistance terms Adding omitted multilateral resistance terms to the error term would invalidate IID and lead to biased estimates of the coefficients. We construct multilateral resistance terms for all bilateral variables and include importer-equivalents for all country-specific variables. Following Baier & Bergstrand (2009), we perform estimation with the equality restrictions implied by (4) imposed. For example, we include the sum of exporter and importer logistics.

Firm-heterogeneity The heterogeneous firms model also indicates potential violation of the IID assumption. Leaving out the control for the proportion of firms exporting would lead to omitted variables bias. Furthermore, the model suggests how country-selection into trade is a function of the variables of interest and a potential source of sample selection bias. To address these issues and implement the heterogeneous firms model, a two-step procedure is needed.

In the first stage, we estimate a probit model for the probability that country j exports to i, denoted ρ_{ij}. Letting T_{ij} be unity when exports from j to i are observed and zero otherwise, we write

$$\rho_{ij} = \Pr(T_{ij} = 1 | \text{Observables,unobservables}) \tag{12}$$

Predicted values of ρ are used to generate normalized predicted values for z, $\hat{z}_{ij}$. The predicted probability $\hat{\rho}_{ij}$ can be used to estimate the inverse Mills ratio $\hat{\eta}_{ij}$, which controls for the country selection effect. Furthermore, HMR show how $\hat{z}_{ij}$ and $\hat{\eta}_{ij}$ can be used to account for firm selection. Define the *propensity to export* $\widehat{x}_{ij} \equiv \hat{z}_{ij} + \hat{\eta}_{ij}$, which is a positive function of ρ_{ij}. This is an estimate of the latent variable z_{ij} as a function of both observable and (an estimate of) unobservable trade frictions. Attaching a Pareto distribution to firm productivities allows us to map $\widehat{x}_{ij}$ to a consistent estimate of the number of firms profitable enough to export. We include this $\widehat{w}_{ij} = \log(e^{\delta \widehat{x}_{ij}} - 1)$, together with $\hat{\eta}_{ij}$, in the second stage of our regression (cf. equation (9)).

We estimate the second stage using non-linear least squares and use bootstrapped standard errors to allow for the fact that we have generated regressors in the second stage.[15] The first stage and homogeneous goods models use standard errors clustered by country-pair. For reliable identification,

[15] We perform 50 replications. Furthermore, we reject draws that spawn theoretically illegitimate values for $\widehat{x}_{ij}$ and $\hat{\eta}_{ij}$.

we need to have one variable in the probit equation that is not in the second stage. Our theoretical framework suggests variables that affect a firm's fixed costs (f_{ij}) of exporting but not its variable costs.

Our first-stage probit only differentiates between zeros and ones, ignoring the missing observations. Baranga (2008) suggests this may induce further selection bias. Addressing these concerns, we also ran specifications in which we estimated a preliminary probit for missing variables. Including an analogous inverse Mills ratio in the "first-stage" probit for positive trade yielded a coefficient of virtually zero with a p-value of close to unity. This suggests ignoring missing values is not an issue for our data. Results are available on request.

Dropping high-income exporters We are interested in the less developed countries. It is quite plausible that the logistics issues faced by richer exporters differ from those faced by poorer exporters such that the gravity parameter λ may differ. Independent of λ, as argued in the theoretical section, MR implies the coefficient on logistics $\frac{\lambda}{n}$ approximates the comparative static effect for an average country in the sample. Excluding the larger countries gives us a better measure of the effect for an average-size developing country. For these reasons, we perform our estimations excluding high income exporters (but including high income importers).

We have another econometric reason for dropping high income exporters: for many country-pairs, very high values of $\hat{\rho}_{ij}$ can be predicted such that they are practically indistinguishable from unity and from one another. Econometric software stores $\hat{\rho}_{ij} = 1$, which prevents calculations of $\hat{\eta}_{ij}$ and $\widehat{x}_{ij}$. HMR truncate the values of $\hat{\rho}_{ij}$ that are greater than 0.9999999 at that value. As a result, there is a mass of estimates of η_{ij} and z_{ij} at a particular value. Baranga (2008) notes that a seemingly innocuous truncation can have a very big impact on estimates of δ. He speculates this may have been done to ensure $\hat{\delta}$ comfortably exceeds zero, which is required for a well-defined gravity model. Preliminary analysis revealed that all our predicted values above 0.9999999 were generated by high-income exporters and that high-income countries generally generated high predicted probabilities. Rather than being stuck with indistinguishable values or truncating arbitrarily, we remove a well defined group of countries, namely high-income exporters.[16]

6. RESULTS

This section discusses the estimation results. In a homogeneous-firm setting, we start with benchmark specifications. We discuss the impact of MR on the estimates and then we assess potential endogeneity. Thereafter, in a heterogeneous-firm setting, we show the results of our two step procedure.

Homogeneous firms In Table 2, column 1 presents a parsimonious specification. We see that the logistics coefficient (on $L_i + L_j$ in all cases unless otherwise specified) is significant and positive. Multilateral resistance for distance is omitted. The coefficient on the product of importer and exporter GDP is close to unity. Column 2 includes a standard set of controls and is representative of what a typical gravity regression, which does not adequately address MR (or selection) in estimation, would produce. The logistics coefficient is 0.481. This would suggest that a one standard deviation improvement in logistics would raise exports 31%. Such a change in logistics corresponds roughly to exports taking two days less to travel from the warehouse to port on average (Arvis, Mustra et al, 2007). It would put Rwanda's logistics on a par with Nigeria's and close to neighbouring Uganda's.

In column 3, we add a full set of controls for MR for each bilateral variable. For example, d_{ij} is replaced with $\left(d_{ij} - MR_{ij}^{dist}\right)$. The logistics coefficient is slightly higher at 0.573. The influence of MR on estimation is minor compared to the comparative static impact we will investigate later.

[16]In the remaining sample, our highest value of $\hat{\rho} = 0.99999997$ is for Mexican exports to the US.

Endogeneity Consistent estimation and the causal interpretation we have just attached assumes the absence of reverse causality and endogeneity bias. For effective IV estimation, we need instruments that have explanatory power (they are sufficiently correlated with logistics) but are exogenous (uncorrelated with exports). While explanatory power can be checked by examining the first-stage regression, the validity is ultimately not testable. We tried a number of plausible candidates.

Column 4 presents the second stage, where the first stage has the number of procedures needed to start a business in the *importer* instrumenting for logistics ($L_i + L_j$). A priori, we expect this to be correlated with our logistics variable, because both variables (specifically, the importer component of logistics) share common institutional bureaucratic features. Furthermore, while the exporter's procedures may or may not be correlated with exports, there is no good reason to believe the importer's procedures should be related with the exporter's exports. In the first stage, the instrument was significant with a p-value of less than 0.0005 (using a t-test or F-test). There is only one instrument so no overidentifying restriction to test. As an informative alternative, we included both exporter and importer procedures as instruments. This yielded a significant Sargan overidentification test (see Wooldridge, 2002:122). Tellingly, the residuals regression produced a significant coefficient for the exporter's procedures but an insignificant coefficient for the importer's procedures.

The coefficient on logistics in column 4 is only slightly lower than in column 3, and the Hausman test for endogeneity was insignificant (with a p-value of 0.73). However, we had a number of alternatives in which the instrument had explanatory power, the overidentification test was insignificant, and the coefficient estimates was higher than in column 3. One example is in column 5, in which we have the sum of procedures in both exporter and importer as one instrument and their product as another. Both variables have explanatory power in the first-stage and the overidentification test was insignificant (with a p-value of 0.76). This means that, conditional on one of these instruments being valid, we can legitimately exclude both. This condition cannot be tested, but our regression of the residuals on the exogenous variables yielded individually and jointly insignificant terms. This generates a coefficient of 0.98 on logistics. However, our specification produces a GDP coefficient that is a little further from unity than we would expect. More importantly, we do not have a good a priori reason to expect these instruments, which have the exporter's bureaucracy as arguments, to be exogenous. Many IV approaches yielded high coefficients like these.[17]

On balance, the evidence is against the OLS coefficient being substantially overestimated due to endogeneity. While column 4 produces an insignificantly lower estimate, column 5 represents estimates which were quite a bit higher. Thus, while instrumentation may be producing higher coefficients, we prefer to keep the column 3 estimate as a conservative measure of the impact. However, as the next section discusses, firm-heterogeneity provides a compelling reason to believe the average impact of logistics is bigger.

Heterogeneous firms Table 3 fully accounts for MR in estimation but also models heterogeneity. Column 1 reproduces column 3 from Table 2 for reference. Column 2 is the result of probit estimates. As in the linear specifications, all variables enter with the expected signs. For example, improved logistics increase the probability of exports. Unlike column 1, the same-country dummy appears significant in the probit. This intuitively suggests that being in what was formerly the same country reduces the fixed costs of exporting but not the variable costs of exporting. We therefore choose to use this variable for identification by excluding it from our second stage regressions.[18]

[17] We experimented with alternative variables and functional form, including the importer's documentation for imports, the importer's documentation for exports, the importer's costs of starting a business, the importer's duration in days of starting a business and combinations thereof. These tended to produce significant coefficients in residuals regressions and/or significant overidentification tests as well as instances of insufficient explanatory power in the first stage.

[18] We tried a number of alternatives, including the religious similarity and regulation variables in Helpman, Melitz & Rubinstein (2008). Possibly because of the year or the omission of rich countries, we found these were not suitable for our data. They often entered the probit with insignificant coefficients and/or the unexpected sign. We also attempted export

In column 3, we estimate the second stage accounting only for country-selection bias.[19] The positive inverse Mills ratio term has the effect of increasing the absolute values of the coefficients, which is consistent with HMR. However, it is insignificant at the 10% level, which suggests country-selection is not an important factor in our data.

In column 4, we account for both selection and heterogeneity. "Delta" is an estimate of the non-linear parameter capturing firm heterogeneity δ. The coefficient is reported as insignificant, but this should not be interpreted as a test of heterogeneity.[20] Consistent with HMR, we find a slightly lower coefficient estimate on the explanatory variables. In particular, the coefficient on logistics is 0.402. As in column 3, the IMR term is insignificant (and slightly negative).[21] We therefore exclude it from our specification in column 5.[22] This generates a slightly lower δ estimate and a slightly higher logistics coefficient of 0.460. As in HMR, the coefficient estimate is lower than in column 1, which implies lower gravity model parameter estimates. However, because this is only at the intensive margin, it does not imply lower country-level effects.

Table 4 in fact demonstrates much higher bilateral country level effects, which are calculated for each country-pair by allowing for the extensive margin (cf. equation (11)). Column 1 presents values based on column 4 of Table 3, which included the IMR. The first row has the firm-level coefficient (0.402) while the second row has a country-level effect that is approximately twice as big on average (0.832). Column 1 reveals some variation in the extensive margin and hence the country-level effect with a standard deviation of 0.125. Column 2 of Table 4 is based on column 5 of Table 3, which excluded the IMR. The distribution of the data is very similar but the mean is higher than in column 1.

The source of variation across country-pairs and hence across income-groups is driven by variations in the extensive margin. Differentiation of (11) with respect to $\hat{x}_{ij}$ would show that the extensive margin effect is higher for countries with a lower value of $\hat{x}_{ij}$, which implies the extensive margin effect is higher for those who tend to have a lower proportion of firms exporting. This in turn implies that countries with lower logistics quality would have a bigger increase in bilateral exports, ceteris paribus.

7. SIMULATIONS: TOTAL COUNTRY-LEVEL EXPORTS

To understand the effects of logistics on a country's total exports in the heterogeneous goods model, we need to aggregate over the bilateral elasticities calculated in Table 4. It is also about time we recognized the importance of MR more explicitly by factoring the actual size of the country. The distribution of world GDP is highly skewed. Only three countries have a GDP share that is above average. In our dataset, the mean is more than ten times as big as the median of world GDP. In our full sample, the world mean is almost *twenty* times as big as that for African countries. By concentrating on the 86 exporters who tend to be smaller, the skewness is reduced slightly. An African country has approximately the median share, which is one fifth of the mean share. Thus, the effect on a particular country or subset of countries can be very different to the average. We illustrate the importance of this issue in a homogeneous setting before performing the aggregation necessary if firms are heterogeneous.

We do not allow for country-level entry in the simulations. While HMR argue very little of the rise

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documentation and/or import documentation in the importer and/or exporter, or combinations theoreof. While these are a priori highly plausible candidates for fixed but not variable trade costs, these also were not suitable identifying variables.

[19] On theoretical grounds, the case can be made that the MR component of fixed costs contribute to multilateral resistance and should be included in the second stage. Including the summation terms associated with the same-country dummy in the second stage made no difference to the results.

[20] The lower bound of any confidence interval must be greater than zero for a well-defined gravity model, so it must be greater by assumption. Furthermore, the term $\ln(e^{\delta\hat{x}_{ij}} - 1)$ is only the $ij-$specific compnent of ω. The rest of it is subsumed in the constant.

[21] A negative coefficient would imply some unobserved feature of the selection equation is negatively correlated with an unobserved feature of the outcome equation. For example, the opportunity to under-report sales increases the profitability of exporting but may reduce the the recorded value of exports.

[22] Arguably, this means we could include the same-country dummy. Manova (2008) does this to test the validity of her identification variable. Doing so yielded an insignificant coefficient on the dummy and practically unchanged results.

in international trade has been due to the formation of new bilateral relationships, this would be an interesting addition to the analysis.[23]

Homogeneous firms Calculating the effect for a particular country j is easy. Equations (3) and (4) imply that we multiply the logistics coefficient by n to get λ and then multiply that by $s_j(1-s_j)$. Using the estimate $\frac{\hat{\lambda}}{n}=0.572$ and $n=86$ gives $\hat{\lambda}\approx 49.25$. Brazil's share of world GDP is 1.84% so its value of $s_j(1-s_j)\hat{\lambda}=0.89$. Table 5 has the (semi-)elasticities for all 86 countries. Brazil's value is in the bottom right. The top left shows many countries whose elasticity is a small fraction of 1%. Browsing the table shows many values are very low. Calculating this for all 86 exporters, we average over these to get the mean elasticity of 0.084. This value, which we call the "typical" elasticity, is substantially less than the elasticity for a country of average-size $\frac{\hat{\lambda}}{n}$ and one tenth the size of Brazil's. South Africa's value of 0.215 is *twenty* times the average for the rest of Sub-Saharan Africa (0.0099). This is not to say that $\frac{\hat{\lambda}}{n}$ is inappropriate: by implicitly giving a greater weighting to bigger countries, it may be a good summary measure, but it is certainly not representative of the typical response.

Heterogeneous firms For each exporter, the elasticity varies by importer when firm heterogeneity is included. Therefore, for each exporter, we sum the bilateral elasticity over all its importers, weighting by the level of exports:[24]

$$\frac{\partial m_j}{\partial L_j}=\frac{1}{\sum_l M_{lj}}\sum_l\left[M_{lj}\frac{\lambda}{n}\left(1+\frac{\delta e^{\delta\hat{x}_{lj}}}{e^{\delta\hat{x}_{lj}}-1}\right)\right]. \tag{13}$$

The average-size *total country* elasticity is 0.73, which implies a one standard deviation improvement in a country's logistics raises exports 46%. This is higher than the homogeneous firms model and the benchmark. To incorporate MR fully, we follow analogous procedures to before; that is, with reference to (10), we compute

$$\xi_j=n\left[s_j(1-s_j)\right]\frac{\partial m_j}{\partial L_j}. \tag{14}$$

ξ_j is a key object of interest and forms the basis for our main substantive result. We expect bigger exporters to have smaller elasticities in general because they have a lower extensive margin effect, but this effect is completely dominated by the MR effect. In other words, the biggest countries (Brazil, India, Mexico) have the biggest elasticities. Table 5 reports the elasticity for each country with respect to an improvement in its own logistics. The average value of ξ_j across 86 exporters is 0.098, which implies a one standard deviation improvement in a country's logistics would raise exports by about 6%. Recall that such an improvement would place Rwanda on a par with Nigeria, but Rwanda's small size means its trade response would be less than 0.3%. This is less than 1% of the 31% implied by the benchmark. In Table 5, Mozambique's elasticity is 0.01. Its logistic quality index value of 2.29 is the median for low income countries and improving it to South Africa's level (3.53) would raise exorts by 1%.

We have seen how modelling MR and firm heterogeneity impact both estimation and comparative statics. By way of summary, we make two final comparisons using estimates we have already presented. Our final estimate of the response to a one standard deviation improvement in logistics quality for a country of average size is 46%. This is somewhat higher than the 31% response implied by our benchmark model in column 2 of Table 2. However, this masks the huge variation in response by country and, due to the skewed distribution of country size, is not typical. Averaging over each country-level response, our measure of the typical response is only 6%, which is one fifth of the effect implied by the benchmark. This difference is an order of magnitude greater than the estimation issues we empirical

[23] HMR's working paper versions have further discussion of this issue.

[24] We did this with actual trade flows but predicted trade flows produced similar results.

economists typically concern ourselves with.

8. ADDITIONAL SPECIFICATIONS

This section conducts further analysis by considering the potential importance of being landlocked and/or poor. We also ask what the role of neighborhood logistics could be. For neighborhoods, we will motivate a reduced form departure from the coefficient restrictions implied by MR. As a result, we do not seek to calculate full comparative statics and return to a homogeneous goods model.

8.1. Landlocked and low-income countries

Rwanda is poor and landlocked. The specifications in Tables 2 and 3 consistently showed a penalty to being landlocked, which is consistent with Limão & Venables (2001). In column 1 of Table 6, we include an interaction between the logistics index and a dummy for whether or not the country is landlocked.[25] There is a negative coefficient on being landlocked as before, but a positive coefficient on the interaction term. This suggests good logistics can counteract the disadvantage, but it would take a high logistics index of about 3.75 to overcome the penalty. The same specification includes an interaction between logistics and income classification. The positive coefficient implies that logistics quality is more important in those countries classified as low income than in those classified as middle income. The coefficients imply a higher trade response for Rwanda, possibly double, but the difference is of second order importance when compared to the impact of MR.

8.2. Neighbourhood logistics

Most countries are not islands. The cost of getting goods to destinations can depend on transit countries, whether for overland trade or to reach a point of departure for ships. To investigate the potential role of neighborhood logistics, we have constructed the unweighted average of a country's neighbors' logistics quality, where neighbors are defined as such if they share a contiguous border. One might suppose that a country's neighbors' logistics facilitate the movement of goods. We would then expect a positive effect of neighbors' logistics on exports. However, it may be the case that exports are negatively associated with neighbors' logistics: a country whose neighbor has good logistics may decide to use that port instead of its own. One example is the choice of exporters in South Africa's Gauteng Province between sending goods via Richard's Bay in South Africa or for re-export via Maputo in Mozambique.[26] Another example is Cotonou, where Benin's main port is seldom used due to high terminal handling fees (Djankov et al).

This paradigm, in which neighboring ports substitute rather than complement one another, is related to MR. If the neighbors' logistics are poor, then the exporter's logistics quality is relatively good, the relative cost of exporting from that exporter is low and hence exports are high (either via the choice of shipment channel, as described above, or because substitute goods are demanded from that country rather than the neighbor). Similarly, the importer's neighbors' logistics act like MR by influencing the relative attractiveness of the importer as an export destination. This proposes a negative relationship between a destination's neighbors' logistics and exports to that destination. Taking the related view that export destinations are substitutes, a particular destination could be an attractive launchpad for serving that market and its neighbors if its logistics are good and the neighbors' logistics are relatively bad. If this is correct, it would be no surprise that Singapore serves as a transport hub (Arvis, Mustra et. al, 2007). In some cases, the data would reflect this as exports from the exporter to the hub (and from the

[25] Specifically, we construct a variable interacting exporter logistics and its landlocked dummy and another variable interacting importer logistics and whether or not the importer is landlocked before summing the two.

[26] Maputo is physically much closer to many factories in South Africa's Gauteng Province, but the border with Mozambique is reportedly slow and the clearance times inferior, so firms choose Richard's Bay. The Maputo Development Corridor initiative aims to improve the lags by improving border transition and introducing a dry dock.

hub to its neighbors) rather than exports from the exporter directly to the neighbors. In contrast, by reducing the costs of transporting goods to the entire region, this may increase exports to that region.

Absent MR, including these variables in an ad hoc way would be straightforward; the sign on each coefficient would indicate the dominance of one effect: positive would indicate complements while negative would indicate substitutes. In the context of MR, interpretation is not so easy. We could naively treat neighborhood logistics as a country-specific variable that is orthogonal to the country's own logistics. The theoretical analysis would motivate inclusion of this variable together with the import partner's neighbors' variable as a control for MR. In column 2 of Table 6, we see an insignificant coefficient on the combined border coefficient. Under this interpretation, it seems there is no dominant effect. However, this naive approach ignores the link between the neighbor logistics variables and the own-logistics data and would rule out the possibility that neighborhood logistics is capturing some MR effects.

To explore this, we include reduced form specifications, which still include the variables necessary to control for MR. In column 3, we include the exporter's neighbors' logistics and the importer's neighbors' logistics, but do not restrict the coefficient. Thus we do not interpret the coefficients strictly in terms of MR nor attempt comparative statics. The exporter-neighbour coefficient is positive. This is consistent with the view that logistics complement one another across countries. However, the negative coefficient on the importer's neighbors' is consistent with countries competing as export destinations and the winners serving as hubs. It can also be interpreted as better neighbors' logistics reducing MR such that bilateral trade is less attractive.

Having relaxed coefficient symmetry for neighbors' logistics, we may as well relax the restrictions on all coefficients. This is done in column 4. Here, we see that the positive coefficient on exporter neighbor logistics is preserved but the importer equivalent is now insignificant (and positive). Relaxing any subset of restrictions (GDP, country-specific variables and bilateral variables) yielded similar results. These reduced form specifications indicate that, while the balance of evidence suggests exporter logistics complement each other, the results for the importer are not robust.[27] They are also subject to potential multicollinearity and identification issues.[28]

The interactions between neighborhoods and MR call for a careful analysis of the spatial structure of trade frictions. As suggested by Anderson & van Wincoop (2004), the evolving literature on spatial econometrics may be useful in this regard. One promising example is that of Behrens, Ertur & Koch (2007), who derive a theoretically founded "dual" gravity equation whose trade flows exhibit a spatially autocorrelated structure.[29] Furthermore, the actual location of the neighbors may be an important factor; Limão & Venables (2001) for example focus on transit countries for landlocked countries

9. CONCLUDING DISCUSSION

We have seen consistent evidence that the exporter's logistics increase exports and preliminary evidence that its neighbors' logistics can also help. Allowing for firm entry into new export markets makes our estimates of the country-level effect bigger than if we just use linear OLS. The regression coefficients indicate the elasticity for a country of average size is 0.73. However, most countries are much smaller than the average, so most countries have much smaller effects. After calculating elasticities for all countries, the typical (mean) elasticity is only 0.098. This implies a one standard deviation improvement in logistics would raise exports by about 6 per cent. The benchmark linear model would have produced estimates of 31% - a four-fold exaggeration. The exaggeration for Rwanda would have been 100-fold.

[27] We also see that, while some unrestricted coefficients on other variables vary from the restricted versions, the results are consistent.

[28] It is for this reason that a number of specifications with additional interactions, for example between landlocked countries and neighbours' logistics, yielded unreliable results.

[29] The spatial weight matrix is populated by a measure of country size and is therefore not too dissimilar from ours. We conjecture that neighbourhoods could be accommodated by taking some account of bordering countries in the spatial weight matrix.

The chief reason for these exaggerations is that standard methods ignore the general equilibrium effects operating through multilateral resistance, which are stronger for smaller countries and hence dampen the trade response by more for them.

One of our key results is that small countries have small elasticities. However, we caution against the interpretation that small countries should not upgrade their logistics. More generally, it does not follow that it is more worthwhile for bigger countries to invest in logistics. The main reason in our context is that costs are likely related to size too. Upgrading logistics for the whole of Mexico is not the same as upgrading in Panama. While introducing more efficient customs procedures may cost the same, upgrading all Mexico's roads would require far more resources. Besides, the functional form we have chosen does not readily allow for decreasing returns, nor does it allow for variations in the gravity parameter λ.[30] More generally, a proper evaluation of welfare gains and costs would be needed.

We have shown dramatic general equilibrium effects in the case of a unilateral improvement in logistics. Wilson et al (2005) simulate the effect of bringing all countries with below-average measures of trade facilitation half way up to the global average. The simulations are based on the gravity regression coefficients but take no explicit account of general equilibrium effects due to multilateral resistance. Thus, a simulation of world trade effects which takes proper account of firm heterogeneity and MR would be a productive enterprise.

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[30] This is standard in the literature. However, this parameter may vary across countries because the products they export may differ (Djankov et al, 2006) or because the elasticity of substitution is not constant. Even so, it would take very large variations in λ to extinguish the relationship between size and the general equilibrium response.

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APPENDIX A: THEORY

There are J countries, $j = 1, ..., J$. Within each country, monopolistically competitive firms produce a continuum of differentiated products l. Consumers have CES preferences with elasticity of substitution $\sigma = \frac{1}{1-\alpha}$. With exogenous income in j of Y_j, firms face demand in country j of $x_j(l) = \frac{Y_j}{P_j^{1-\sigma}} p_j(l)^{-\sigma}$,where $p_j(l)$ is the price of variety l in j and P_j is j's ideal price index $P_j = \left[\int_l p_j(l)^{1-\sigma} dl\right]^{\frac{1}{1-\sigma}}$.

A.1. Homogeneous firms model

A.1.1. Production

Each country produces N_j exogenous varieties - one per firm. Firms face input unit requirement $a = 1$ and 'iceberg' variable trade costs $t_{ij} > 1$. For every destination, firms price to maximize profit, which gives $p_{ij} = \frac{t_{ij}}{\alpha}$. The total value of imports by country i from country j is given by $M_{ij} = p_{ij} x_{ij} N_j$. Substituting in for prices and quantities, we obtain

$$M_{ij} = \frac{Y_i}{P_i^{1-\sigma}} \left(\frac{t_{ij}}{\alpha}\right)^{1-\sigma} N_j. \tag{15}$$

Using $p_{ij} = t_{ij}/\alpha$ the price index can be written $P_i^{1-\sigma} = \sum_j (t_{ij}/\alpha)^{1-\sigma} N_j$.

A.1.2. General Equilibrium

Assume trade balance for each country, such that $Y_j = \sum_i M_{ij}$. Algebraic manipulation and substitution in (15) gives

$$M_{ij} = \frac{Y_i Y_j}{Y} \left(\frac{t_{ij}}{P_i}\right)^{1-\sigma} \frac{1}{\sum_i \left(\frac{t_{ij}}{P_i}\right)^{1-\sigma} s_i}, \tag{16}$$

where $s_i = Y_i/Y$. Then define $P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{P_i}\right)^{1-\sigma} s_i$, such that $P_i^{1-\sigma} = \sum_j (t_{ij})^{1-\sigma} \frac{s_j}{\sum_i \left(\frac{t_{ij}}{P_i}\right)^{1-\sigma} s_i}$ and

$$\begin{aligned} P_i^{1-\sigma} &= \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} s_j, \\ P_j^{1-\sigma} &= \sum_i \left(\frac{t_{ij}}{P_i}\right)^{1-\sigma} s_i, \end{aligned}$$

which are the multilateral resistance (MR) terms. Using these in (16) gives the AvW gravity equation:

$$M_{ij} = \frac{Y_i Y_j}{Y} \left(\frac{t_{ij}}{P_i P_j}\right)^{1-\sigma}$$

or, in logs,

$$m_{ij} = y_i + y_j - y - (\sigma - 1) \ln t_{ij} + (\sigma - 1) \ln(P_i P_j). \tag{17}$$

Baier and Bergstrand (2009) show that MR can be approximated using a first-order Taylor expansion:

$$\ln (P_i P_j)^{\sigma-1} = \underbrace{-\sum_k s_k \sum_h s_h \ln t_{kh}^{\sigma-1}}_{\text{World Trade Resistance}} + \underbrace{\sum_h s_h \ln t_{ih}^{\sigma-1}}_{\text{Importer's MR}} + \underbrace{\sum_k s_k \ln t_{kj}^{\sigma-1}}_{\text{Exporter's MR}} \tag{18}$$

We specify iceberg costs in terms of logistics quality and the logarithm of distance: $\ln t_{ij}^{\sigma-1} = \gamma d_{ij} - \lambda L_j$ yields

$$\ln (P_i P_j)^{\sigma-1} = \gamma MR_{ij}^{dist} - \lambda MR_{ij}^{logistics},$$

where

$$MR_{ij}^{dist} \equiv -\sum_k \sum_h s_k s_h d_{kh} + \sum_h s_h d_{ih} + \sum_k s_k d_{kj}, \quad (19)$$

$$MR_{ij}^{logistics} \equiv -\sum_k \sum_h s_k s_h L_h + \sum_h s_h L_h + \sum_k s_k L_j. \quad (20)$$

To understand the comparative static effects of logistics quality on *cross-border* trade, we let logistics change when $k \neq j$ and $h \neq i$. Such comparative statics yield equation (3a) in the text:

$$\left.\frac{\partial m_{ij}}{\partial L_j}\right|_{\text{homog.}} = \lambda \{1 + s_j (1 - s_j) - s_j - (1 - s_j)\} \quad (21)$$

A.2. Heterogeneous firms model

A.2.1. Production

As in Melitz (2003), firms draw input unit cost requirement a independently from the identical distribution function $G(a)$ with support $[a_L, a_H]$. There are two types of cost of exporting. As before, there is an 'iceberg' variable trade cost $t_{ij} > 1$. The second type of barrier to trade is a fixed cost of exporting $f_{ij} > 0$, $f_{ii} = 0$. Taken together, a firm in j exporting to i producing q_{ij} units of output has a cost function given by

$$C_{ij}(a) = a t_{ij} q_{ij} + f_{ij}. \quad (22)$$

This gives the standard price and profit function for a firm exporting from j to i as

$$p_{ij}(a) = \frac{t_{ij} a}{\alpha}, \quad (23)$$

$$\pi_{ij}(a) = (1 - \alpha) \left[\frac{t_{ij} a}{\alpha P_i}\right]^{1-\sigma} Y_i - f_{ij}. \quad (24)$$

Sales by firms in country j are only profitable in country i if $\pi_{ij}(a) > 0$. Hence we define a productivity cut-off a_{ij} by $\pi_{ij}(a_{ij}) = 0$, which is the cost level below which it is profitable to export. Firms with $a > a_{ij}$ do not generate profits high enough to cover the fixed costs of exporting f_{ij}. Using an exporting firm's profit function above then gives us the cut-off as

$$a_{ij} = \left[\frac{Y_i(1 - \alpha)}{f_{ij}}\right]^{\frac{1}{\sigma-1}} \frac{\alpha P_i}{t_{ij}}. \quad (25)$$

This gives us the *extensive margin* of trade. Whenever $a_L < a_{ij} < a_H$, there will be firm selection into exporting. In particular, firms with the highest variable costs will choose not to export. The total value of imports by country i from country j is given by $M_{ij} = \int_{a_L}^{a_{ij}} p_{ij} q_i N_j dG(a)$. Substituting in for prices and quantities, we obtain an analogue of equation (6) in Helpman, Melitz & Rubinstein (2008):

$$M_{ij} = \left[\frac{t_{ij}}{\alpha P_i}\right]^{1-\sigma} N_j Y_i V_{ij}. \quad (26)$$

$V_{ij} \equiv \int_{a_L}^{a_{ij}} a^{1-\sigma} dG(a)$ captures the firm selection effect. As a_{ij} rises, V_{ij} rises.

A.2.2. General Equilibrium

Assuming $Y_j = \sum_i M_{ij}$ allows one to write equation (6) in the text:

$$M_{ij} = \frac{Y_i Y_j}{Y} \left(\frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} V_{ij}. \tag{27}$$

Equation (27) provides the basis for our empirical heterogeneous firms model, which incorporates MR in an analogous manner to the homogeneous firms model.[31]

[31] In a heterogeneous setting, the price terms should arguably only be a function of actively traded goods. See Behar and Nelson (2009). We abstract from this for simplicity.

Income Group	mean	standard deviation	25th percentile	median	75th percentile	minimum	maximum
High	3.73	0.35	3.52	3.84	4	3.02	4.19
Middle	2.64	0.38	2.37	2.57	2.89	1.94	3.53
Low	2.33	0.26	2.16	2.29	2.47	1.77	3.07
Overall	2.78	0.63	2.31	2.55	3.15	1.77	4.19

Table 1: Summary statistics for logistics quality; richer countries have better logistics on average, but there is overlap between income groups. Source: http://go.worldbank.org/88X6PU5GV0. World Bank income classifications. Authors' calculations.

Dependent variable: bilateral exports	-1 Simple	-2 Controls	-3 MR controls	-4 IV 1	-5 IV 2
GDP	1.036***	1.004***	0.932***	0.940***	0.855***
Logistics	0.324***	0.481***	0.573***	0.530***	0.982***
Distance	-1.729***	-1.452***	-1.557***	-1.554***	-1.588***
Border		1.522***	1.195***	1.193***	1.212***
Language		0.535***	0.729***	0.729***	0.730***
Colony		1.034***	0.864***	0.862***	0.882***
Landlocked		-0.584***	-0.467***	-0.463***	-0.504***
Same-country		0.368*	0.245	0.250	0.200
Constant	-22.32***	-34.73***	-33.39***	-33.55***	-31.90***
N	6322	6322	6322	6322	6322
adj. R-sq	0.552	0.578	0.57	0.57	0.566

Table 2: Gravity regression results for homogeneous firm model. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. Logistics is significant in all specifications, but introducing MR raises the coefficient. Column 2 is a benchmark. Columns 3-5 account for MR fully. Column 3 is OLS and column 4 gives an insignificantly different IV specification but higher coefficients can be generated with IV specifications such as column 5.

Dependent variable: bilateral exports	-1	-2	-3	-4	-5
	Homogeneous (no selection)	Probit	Country selection	Country/firm selection	Firm selection
GDP	0.932***	0.257***	0.958***	0.828***	0.864***
Logistics	0.573***	0.406***	0.611***	0.402**	0.460***
Distance	-1.557***	-0.576***	-1.616***	-1.310***	-1.394***
Border	1.195***	0.187	1.252***	1.103***	1.142***
Language	0.729***	0.453***	0.771***	0.538**	0.602***
Colony	0.864***	0.185**	0.932***	0.811***	0.847***
Landlocked	-0.467***	-0.106***	-0.479***	-0.425***	-0.441***
Same-country	0.245	0.539***			
IMR			0.325	-0.165	
Delta				0.517	0.385*
Constant	-33.39***	-13.47***	-34.96***	-27.13***	-29.07***
N	6322	8652	6322	6322	6322
adj. R-sq	0.57		0.57	0.57	0.57

Table 3: Gravity regression results introducing selection. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. Column 2 is probit used in first stage; columns 3-5 are alternative second stages. As in HMR, the logistics coefficient is higher in column 3 than in the no-selection case but lower in columns 4 & 5.

	Statistic	Country/firm Selection (1)	Firm Selection (2)
Firm-level		0.402	0.460
Country-level	mean	0.832	0.915
	std dev	0.125	0.146
	min	0.623	0.662
	p25	0.735	0.802
	p50	0.810	0.890
	p75	0.910	1.006
	max	1.393	1.561
	N	6322	6322

Table 4: Summary statistics for bilateral elasticities. The statistics refer to elasticities generated by columns 4 & 5 of Table 2 while the elasticity implied by the homogeneous firm model is 0.57 (cf. column 1).

Exporter	Share %	Homogeneou	Heterogeneou
Guinea-Bissau	0.001	0.0003	0.0005
Gambia	0.001	0.0007	0.0010
Djibouti	0.002	0.0009	0.0013
Guyana	0.002	0.0010	0.0014
Burundi	0.002	0.0011	0.0016
Mongolia	0.003	0.0017	0.0023
Sierra	0.003	0.0016	0.0025
Mauritania	0.004	0.0018	0.0025
Togo	0.004	0.0020	0.0029
Tajikistan	0.004	0.0021	0.0030
Kyrgyz Republic	0.005	0.0022	0.0031
Moldova	0.005	0.0024	0.0033
Malawi	0.005	0.0027	0.0038
Lao	0.006	0.0032	0.0039
Niger	0.006	0.0030	0.0040
Chad	0.007	0.0035	0.0047
Rwanda	**0.006**	**0.0032**	**0.0047**
Benin	0.008	0.0037	0.0054
Haiti	0.010	0.0050	0.0059
Macedonia	0.011	0.0052	0.0065
Papua	0.010	0.0051	0.0066
Mali	0.009	0.0045	0.0067
Burkina Faso	0.009	0.0045	0.0067
Guinea	0.010	0.0049	0.0069
Nicaragua	0.013	0.0062	0.0073
Zambia	0.011	0.0055	0.0075
Albania	0.013	0.0065	0.0079
Gabon	0.015	0.0073	0.0094
Zimbabwe	0.015	0.0075	0.0096
Senegal	0.015	0.0075	0.0103
Mozambique	0.016	0.0078	0.0103
Nepal	0.017	0.0086	0.0105
Honduras	0.019	0.0096	0.0111
Ghana	0.017	0.0086	0.0118
Paraguay	0.022	0.0109	0.0134
Uganda	0.021	0.0105	0.0144
Bolivia	0.027	0.0132	0.0159
Ethiopia	0.028	0.0135	0.0182
Cote d'Ivoire	0.029	0.0142	0.0188
Jordan	0.031	0.0154	0.0189
Yemen	0.031	0.0150	0.0195
Cameroon	0.033	0.0163	0.0211
El Salvador	0.040	0.0198	0.0224
Tanzania	0.035	0.0171	0.0227
Panama	0.039	0.0193	0.0227
Kenya	0.042	0.0205	0.0258
Bulgaria	0.044	0.0217	0.0262
Lithuania	0.045	0.0224	0.0269
Sudan	0.046	0.0226	0.0290
Costa Rica	0.053	0.0263	0.0310
Uzbekistan	0.049	0.0242	0.0321
Ecuador	0.056	0.0277	0.0323
Guatemala	0.060	0.0295	0.0338
Lebanon	0.056	0.0274	0.0344
Uruguay	0.059	0.0292	0.0356
Dominican	0.064	0.0316	0.0362
Croatia	0.064	0.0313	0.0368
Syrian	0.061	0.0302	0.0377
Tunisia	0.066	0.0327	0.0387
Slovak	0.070	0.0347	0.0405
Morocco	0.112	0.0553	0.0670
Vietnam	0.123	0.0604	0.0711
Ukraine	0.124	0.0611	0.0762
Romania	0.134	0.0660	0.0780
Hungary	0.158	0.0779	0.0904
Nigeria	0.166	0.0816	0.0985
Bangladesh	0.169	0.0829	0.0998
Peru	0.179	0.0882	0.1028
Algeria	0.191	0.0941	0.1129
Chile	0.256	0.1258	0.1466
Pakistan	0.255	0.1252	0.1503
Colombia	0.272	0.1337	0.1535
Malaysia	0.309	0.1517	0.1724
Egypt	0.330	0.1621	0.1959
Venezuela	0.361	0.1769	0.1998
Iran	0.364	0.1788	0.2158
Thailand	0.431	0.2111	0.2440
South Africa	0.439	0.2151	0.2525
Poland	0.545	0.2672	0.3051
Indonesia	0.571	0.2794	0.3229
Turkey	0.676	0.3308	0.3855
Argentina	0.861	0.4206	0.4887
Russia	0.961	0.4687	0.5554
Mexico	1.747	0.8457	0.9263
India	1.769	0.8559	0.9893
Brazil	1.841	0.8903	1.0361
MEAN	0.172	0.084	0.098

Table 5: Country-level elasticities after accounting for MR. Elasticities for each country assume that country improves its logistics quality by one unit, but no other country does so.

Dependent variable: bilateral exports	-1	-2	-3	-4
GDP	0.957***	0.935***	0.918***	
Logistics	0.534***	0.585***	0.820***	
Distance	-1.563***	-1.538***	-1.503***	-1.590***
Border	1.192***	1.231***	1.238***	1.162***
Language	0.757***	0.756***	0.791***	0.966***
Landlocked	-1.556***	-0.472***	-0.443***	
Colony	0.831***	0.867***	0.847***	0.665***
Same-country	0.244	0.221	0.249	0.284
Logistics*Low	0.117***			
Logistics*Landlocked	0.407***			
Neighbors		-0.0224		
Exporter Neighbor			0.752***	0.364***
Importer Neighbor			-0.481***	0.124
Exporter GDP				1.149***
Importer GDP				0.825***
Exporter Logistics				1.475***
Importer Logistics				0.463***
Exporter Landlocked				-0.148*
Importer Landlocked				-0.755***
Constant	-34.51***	-33.47***	-34.65***	-29.37***
N	6322	6272	6272	6272
adj. R-sq	0.572	0.57	0.578	0.626

Table 6: Alternative regression specifications. Significance levels: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Column 1 shows poor and landlocked countries gain more from improved logistics, column 2 indicates neighborhood logistics is insignificant, but less restricted versions in columns 3 & 4 suggest some potential significant impacts.