International Trade: Linking Micro and Macro\footnote{An earlier draft of this paper was presented at the Econometric Society World Congress, Paired Invited Session on Trade and Firm Dynamics, in Shanghai in August 2010. It was published in the volume edited by Daron Acemoglu, Manuel Arellano, and Eddie Dekel, \textit{Advances in Economics and Econometrics, Tenth World Congress, Volume II, Applied Economics}, Cambridge University Press, 2013, 329-370. We have benefited from the valuable comments of Daron Acemoglu, Costas Arkolakis, Thomas Chaney, Peter Egger, Elhanan Helpman, Stephen Redding, Joao Santos Silva, Silvana Tenreyro, and Alain Trognon. Kelsey Moser provided excellent research assistance. Alvin Chung and Michelle Tong carefully revised this draft to be consistent with the published version. We gratefully acknowledge the support of the National Science Foundation under grant numbers SES-0339085 and SES-0820338.}}

Jonathan Eaton, Samuel Kortum, and Sebastian Sotelo
Abstract

A recent literature has introduced heterogeneous firms into models of international trade. This literature has adopted the convention of treating individual firms as points on a continuum. While the continuum offers many advantages this convenience comes at some cost: (1) Shocks to individual firms can never have an aggregate effect. (2) It is hard to reconcile the small (sometimes zero) number of firms engaged in selling from one country to another with a continuum. (3) For such models to deliver finite solutions for aggregates, such as the price index, requires restrictions on parameter values that may not hold in the data. We show how a standard heterogeneous-firm trade model can be amended to allow for only an integer number of firms. The model overcomes the deficiencies of the continuum model enumerated above. Taking the model to aggregate data on bilateral trade in manufactures among 92 countries and to firm-level export data for a much narrower sample shows that it accounts for both the large share of a small number of firms in sales around the world and for zeros in bilateral trade data while maintaining the good fit of the standard gravity equation among country pairs with thick trade volumes. Randomness at the firm level adds substantially to aggregate variability.
1 Introduction

The field of international trade has advanced in the past decade through a healthy exchange between new observations on firms in export markets and new theories that have introduced producer heterogeneity into trade models. As a result, we now have general equilibrium theories of trade that are consistent with various dimensions of both the aggregate and the firm-level data. Furthermore, we have a much better sense of the magnitudes of key parameters underlying these theories.\footnote{Bernard, Jensen, Redding, and Schott (2007) and, more recently, Redding (2011) provide surveys.}

This flurry of activity at the firm level has left the core aggregate relationships among trade, factor costs, and welfare largely untouched, however. Although we now have much better microfoundations for aggregate trade models, their predictions are much like those of the Armington model – for years a workhorse of quantitative international trade. Arkolakis, Costinot, and Rodríguez-Clare (2012) emphasize this (lack of) implication of the recent literature for aggregate trade.

We argue that a primary reason why models of heterogeneous producers deliver so little in the way of modification of how we think about aggregates is the device – initiated in the trade literature by Dornbusch, Fischer, and Samuelson (1977) – of treating the set of products as a continuum. The heterogeneous-firm literature embraced this approach, applying it to individual producers.

Treating individual producers as points on a continuum has a number of extremely convenient implications that the field (including work by two of the authors of this chapter) has exploited relentlessly. With a continuum, each producer has measure zero, so it has no effect
on aggregates. Invoking the law of large numbers, we are free to model what goes on at the aggregate level as driven by the parameters (which may be small in number) governing the distributions of the outcomes affecting individual units but not on the realizations of those outcomes themselves. With the right distributional assumptions about the processes underlying the outcomes of individual firms, one can readily integrate over them to get simple and familiar aggregate relationships. The continuum thus provides a wall of separation between smooth aggregate relationships and potentially jagged heterogeneity underneath, allowing us to deal with each realm in isolation.

Of course, the number of producers or products is not literally a continuum. Yet, are they so numerous that treating them as a continuum is an innocuous simplification? For many purposes, it undoubtedly is, but there are questions for which the continuum can lead us astray. First, some individual producers may indeed loom so large that their own individual fates have implications for the economy as a whole. Second, under the continuum assumption, anything that can happen (within the support of what is modeled as possible), will happen. An implication, for example, is that if we observe no exports from one country to another, as we often do, then exporting was impossible – not that it just so happened that no firm found exporting worthwhile. A third limitation is that obtaining well-behaved integrals across the continuum requires restrictions on distributional parameters that prevent the size distribution of firms from becoming too skewed. The skewness observed in the data is uncomfortably close to the limits imposed by these parameter restrictions.

Here, we explore the implications of having only a finite number (sometimes zero) of firms exporting. We develop a variant of a standard model of firm participation in exporting in
which the number of firms is an integer. The model confronts each of the issues raised in
the previous paragraph: (1) Under parameter values consistent with the data, randomness in
the situations of individual firms translates into substantial randomness in aggregates such
as the price index; (2) the model predicts zero trade flows, with a frequency similar to what
we see in the data, simply because no firm happened to be efficient enough – not because
it was impossible for any firm whatever its luck of the draw; and (3) Our finite-firm model
can easily deal with parameter values consistent with any degree of skewness in the firm-size
distribution.

We use our model to perform a series of quantitative exercises. We first derive the model’s
implication for the specification of a gravity equation. Estimating this equation with aggre-
gate bilateral trade and production data delivers estimates of the parameters governing the
probability of a firm from each source entering each destination. We then take the model to
firm-level data to learn about the cost of entry in different markets (and the other remaining
parameters). With a fully parameterized version of the model in hand, we conduct two ex-
periments. The first addresses the zeros issue. A simulation of 10 percent lower trade barriers
worldwide introduces 206 new bilateral trading relationships (although the amount of trade
involved is miniscule). The second gets to the heart of the law-of-large-numbers question. We
find that resampling repeatedly the efficiencies of individual firms around the world generates
a variance (of percentage deviations) in the manufacturing price index for the United States
of 14 and for Denmark of 24 – far from the zero implied by a continuum model.

This chapter addresses a particular situation in which an aggregate relationship (here, a
bilateral trade flow) is the outcome of decisions by heterogeneous individual agents (here, of
firms on whether and how much to export to a destination). However, the issues we raise apply to any aggregate variable (e.g., consumption or investment) whose magnitude is the summation of what a diverse set of individuals choose to do, which may include nothing.

The chapter proceeds as follows. We begin with a review of related literature followed by an overview of key features of the trade data. Next, we introduce our finite-firm model, which underlies the estimation approach that follows. We then confront the model with the data introduced in the previous section.

2 Related Literature

This chapter relates closely to another literature that emphasized the importance of individual firms in aggregate models. Gabaix (2011) used such a structure to explain aggregate fluctuations due to shocks to very large firms in the economy. This analysis is extended to international trade by Canals, Gabaix, Vilarrubia, and Weinstein (2007) and di Giovanni and Levchenko (2009), again highlighting the role of very large firms in generating aggregate fluctuations.

The literature on zeros in the bilateral-trade data includes Eaton and Tamura (1994); Santos Silva and Tenreyro (2006); Armenter and Koren (2008), Helpman, Melitz, and Rubinstein (2008), Martin and Pham (2008); and Baldwin and Harrigan (2011). Our underlying model of trade relates closely to Helpman, Melitz, and Rubinstein (2008), but rather than obtaining zeros by truncating a continuous Pareto distribution of efficiencies from above, zeros arise in our model because – as in reality – the number of firms is finite. Like us, Armenter and Koren (2008) assume a finite number of firms, stressing, as we do, the importance of the sparsity of
the trade data in explaining zeros. Theirs, however, was a purely probabilistic rather than an economic model.\footnote{Mariscal (2010) showed that the Armenter and Koren (2008) approach also goes a long way in explaining multinational expansion patterns.}

Our work also touches on Balistreri, Hillberry, and Rutherford (2011). Their paper discussed both estimation and general equilibrium simulation of a heterogeneous-firm model similar to the one we consider here. However, it does not draw out the implications of a finite number of firms, which is our main contribution.

Finally, a recent paper by Armenter and Koren (2012) took an approach complementary to ours in this chapter. In their framework individual buyers, rather than sellers, are finite in number, generating the possibility of zero sales.

\section{The Data}

We use macrodata and microdata on bilateral trade in manufactures among 92 countries. The macrodata are aggregate bilateral trade flows (in U.S. dollars) of manufactures $X_{ni}$ from source country $i$ to destination country $n$ in 1992 (Feenstra, Lipsey, and Bowen 1997) and aggregate manufacturing production (described in Eaton, Kortum, and Kramarz 2011). The microdata are firm-level exports to destination $n$ for four exporting countries $i$. The efforts of many researchers, who exploited customs records, are making such data more widely available. We were generously provided microdata for exports from Brazil, France, Denmark, and Uruguay.\footnote{The French data for manufacturing firms in 1992 are from Eaton, Kortum, and Kramarz (2011). The Danish data for all exporting firms in 1993 are from Pedersen (2009). The Brazilian data for manufactured exports in 1992 are from Arkolakis and Muendler (2010). The Uruguayan data for 1992 and 1993 were compiled}
The microdata allow us to measure the number $K_{ni}$ of firms from $i$ selling in $n$ as well as mean sales per firm $\overline{X}_{ni}$ when $K_{ni}$ is reported as positive.\(^4\) In merging the data, we chose our 92 countries for the macrolevel analysis in order to have observations at the firm level from at least two of our four sources.

**Figure 1. Micro and macro bilateral trade**

Table 1 lists our 92 countries and each country’s total exports to and imports from the other 91. The last two columns display the number of destinations for each country’s exports and the number of sources for its imports (each out of a maximum of 91). It is not surprising that a country trades with a greater number of other countries when it trades more in total.

\(^4\)We cannot always determine in the export microdata if the lack of any reported exporter to a particular destination means zero exports there or that the particular destination was not in the dataset. Hence, our approach, which exploits the micro data only when $K_{ni} > 0$, leaves open the interpretation.
Table 1. Trade in manufactures

<table>
<thead>
<tr>
<th>Country</th>
<th>Value of trade (Million USD)</th>
<th>Trade partners in sample (out of a total of 91)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total exports</td>
<td>Total imports</td>
</tr>
<tr>
<td>Algeria</td>
<td>262.02</td>
<td>6230.41</td>
</tr>
<tr>
<td>Angola</td>
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<td>2149.29</td>
</tr>
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<td>Argentina</td>
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<tr>
<td>Australia</td>
<td>15566.94</td>
<td>30132.72</td>
</tr>
<tr>
<td>Austria</td>
<td>22085.23</td>
<td>21720.69</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>1446.20</td>
<td>1188.85</td>
</tr>
<tr>
<td>Benin</td>
<td>15.96</td>
<td>448.10</td>
</tr>
<tr>
<td>Bolivia</td>
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<td>1111.53</td>
</tr>
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<td>Brazil</td>
<td>27212.22</td>
<td>13626.56</td>
</tr>
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<td>Bulgaria</td>
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<td>1283.07</td>
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<tr>
<td>Burkina Faso</td>
<td>26.11</td>
<td>232.03</td>
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<td>Burundi</td>
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<td>88.01</td>
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<td>Cameroon</td>
<td>390.73</td>
<td>877.53</td>
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<td>Canada</td>
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<td>1172.92</td>
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<td>Kuwait</td>
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<thead>
<tr>
<th>Country</th>
<th>Value of trade (Million USD)</th>
<th>Trade partners in sample (out of a total of 91)</th>
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</thead>
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<td></td>
<td>Total exports</td>
<td>Total imports</td>
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<td>54 Morocco</td>
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<td>55 Mozambique</td>
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<td>66 Philippines</td>
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<td>67 Portugal</td>
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<td>68 Romania</td>
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<td>2094.73</td>
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<td>71 Senegal</td>
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<td>72 South Africa</td>
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<td>74 Sri Lanka</td>
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<td>80 Thailand</td>
<td>21645.97</td>
<td>27416.26</td>
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<tr>
<td>81 Togo</td>
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<tr>
<td>82 Trinidad and Tobago</td>
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<td>83 Tunisia</td>
<td>2230.96</td>
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<tr>
<td>84 Turkey</td>
<td>6824.79</td>
<td>12386.31</td>
</tr>
<tr>
<td>85 Uganda</td>
<td>23.50</td>
<td>266.95</td>
</tr>
<tr>
<td>86 United Kingdom</td>
<td>128688.75</td>
<td>137566.47</td>
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<tr>
<td>87 United States of America</td>
<td>359292.84</td>
<td>395010.78</td>
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<tr>
<td>88 Uruguay</td>
<td>1324.24</td>
<td>1672.66</td>
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<tr>
<td>89 Venezuela</td>
<td>2819.75</td>
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<td>90 Viet Nam</td>
<td>833.21</td>
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<tr>
<td>91 Zambia</td>
<td>912.95</td>
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<tr>
<td>92 Zimbabwe</td>
<td>555.31</td>
<td>1286.70</td>
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<tr>
<td>Average</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Nonetheless, the number of zero trade links is large, comprising more than one third of the
8,372 bilateral observations.

The average number of positive bilateral trade flows per country, either as an exporter or
an importer, is 59.6. The variance of the number of export destinations, however, is 652.5
while the variance of the number of import sources is only 283.6. As we discuss in Section
5.2, our analysis provides an explanation for the large deviation between the variances.

For country pairs for which $K_{ni} > 0$, Figure 1 plots $K_{ni}$ against $X_{ni}$ on log scales, with
source countries labeled by the first letter of the country name. The data cluster around a
positively-sloped line, with no apparent differences across the four source countries.\footnote{The regression slope is 0.71 (standard error 0.17), slightly higher than the 0.65 Eaton, Kortum, and
Kramarz (hereafter EKK, 2011) found for French firms in 1986. Allowing for source-specific intercepts (which
differ significantly from a common intercept), we cannot reject the hypothesis of a common slope of 0.62 (with
a standard error of 0.03).}

Where exporting does occur, how important are very large firms? Using data on individual
French firms in 1986, we order exporters according to their total exports.\footnote{The sample consists of 34,035 French exporters, described in EKK (2011). We consider exports to the
112 destinations reported in that paper. Canals, Gabaix, Vilarrubia, and Weinstein (2007) reported results
for Japanese exporters similar to those for France in Table 2. Freund and Pierola (2012) find, among 33
developing countries, that the top 1 percent of exporting firms typically account for more than half of export
revenues. The number of such export "superstars" averages 54, and for 8 countries there are fewer than 10.}

Table 2 reports
the contribution to total French exports of the top 10, 100, 1000, and 10,000 largest French
exporters. The 100 largest exporters account for nearly half of total exports – nearly half of
which is due to only the top 10 exporters. These same firms are the main contributors to
French exports to individual destinations as well.
Table 2. Share of largest French exporters

<table>
<thead>
<tr>
<th>French exports to:</th>
<th>Everywhere</th>
<th>United States</th>
<th>Denmark</th>
<th>Shares across destinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 10</td>
<td>23.6</td>
<td>22.4</td>
<td>22.2</td>
<td>18.9</td>
</tr>
<tr>
<td>Top 100</td>
<td>47.9</td>
<td>54.6</td>
<td>52.2</td>
<td>16.8</td>
</tr>
<tr>
<td>Top 1,000</td>
<td>80.5</td>
<td>84.8</td>
<td>83.5</td>
<td>12.4</td>
</tr>
<tr>
<td>Top 10,000</td>
<td>98.9</td>
<td>99.3</td>
<td>99.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

For example, Table 2 shows that the top 100 French exporters account for more than half of French exports to both the United States and Denmark. Although the United States and Denmark are typical, the last column of the table shows that these statistics vary considerably among countries.

4 A Finite-Firm Model of Trade

Our framework relates closely to work on trade with heterogeneous firms in Melitz (2003), Chaney (2008), and EKK (2011). The key difference is that we treat the range of potential technologies for these firms not as a continuum but rather as an integer. Some results from the existing work survive, others do not. We show the difficulties introduced by dropping the continuum and an approach to overcoming them. To highlight the similarities and differences, we report established results from the continuum case in parallel with our finite-firm variant.

4.1 Technology

As in the recent literature (but also close to the basic Ricardian model of international trade), our basic unit of analysis is a technology for producing a unique good. We represent technology
by the quantity $Z$ of output produced by a unit of labor.\footnote{A higher $Z$ can mean: (1) more of a product, (2) the same amount of a better product, or (3) any combination of the first two that renders the output of the good produced by a worker more valuable. For the results here the different interpretations have isomorphic implications. Here, “labor” can be interpreted to mean an arbitrary bundle of factors and the “wage” to mean the price of that bundle, common across all goods $j$. Eaton and Kortum (2002) and EKK (2011) made the input bundle a Cobb-Douglas combination of labor and intermediates, an extension we do not pursue in this chapter.} We refer to $Z$ as the efficiency of the technology. We call the owner of this technology a firm, even though – in equilibrium – many of these “firms” will be inactive.

A standard building block in modeling firm heterogeneity is the Pareto distribution of firm efficiency. We follow this tradition in assuming that for any given firm, conditional on its efficiency exceeding some threshold $z > 0$, its efficiency is the realization of a random variable $Z$ drawn from a Pareto distribution with parameter $\theta > 0$, so that:

$$\Pr(Z > z | Z \geq z) = \left(\frac{z}{z^*}\right)^{-\theta}.$$  

The Pareto distribution has a number of properties that make it analytically very tractable.\footnote{To list a few: (1) Integrating across functions weighted by the Pareto density often yields simple closed-form solutions. Hence, for example, if a continuum of firms are charging prices that are distributed Pareto, under standard assumptions about preferences, a closed-form solution for the price index emerges. (2) Truncating the Pareto distribution from below yields a Pareto distribution with the same shape parameter $\theta$. Hence, as we assume subsequently, if entry is subject to a cutoff, the distribution of the technologies that make the cut remains Pareto. (3) A Pareto random variable taken to a power is also Pareto. Hence, if individual prices have a Pareto distribution, with a constant elasticity of demand, so also do sales.} Moreover, for reasons that were discussed by Simon and Bonini (1958), Gabaix (1999), and Luttmer (2011), the relevant data (e.g., firm-size distributions) often exhibit Pareto properties, at least in the upper tail.
4.1.1 Continuum Case

With a continuum of firms, the measure of firms with efficiency greater than $z$ is thus proportional to $z^{-\theta}$. Hence, we can write the measure of firms in country $i$ with efficiency $Z \geq z$ as:

$$\mu_i^Z(z) = T_i z^{-\theta}$$  \hspace{1cm} (2)

where $T_i > 0$ is a parameter reflecting the overall measure of firms in country $i$.

4.1.2 Finite-Firm Case

We propose an alternative in which, instead, each country $i$ has access to an integer number of technologies, with the number having efficiency $Z \geq z$ the realization of a Poisson random variable with parameter $\mu_i^Z(z) = T_i z^{-\theta}$ (instead of a measure $\mu_i^Z(z)$).\(^9\) It is useful to rank these technologies according to their efficiency; that is, $Z_{i}^{(1)} > Z_{i}^{(2)} > Z_{i}^{(3)} > ... > Z_{i}^{(k)} > ...$.

\(^9\)In either specification, the level of $T_i$ may reflect a history of innovation, as discussed in Eaton and Kortum (2010, Chapter 4). Furthermore, $z$ can be set arbitrarily close to zero. For the finite-firm case, for example, we can consider taking $D$ draws from the Pareto distribution (1), where $D$ is distributed Poisson with parameter $T z^{-\theta}$. The number of draws for which $Z > z$ is distributed Poisson with parameter $T z^{-\theta}$, as we previously assume. The largest $Z$, called $Z^{(1)}$, is distributed:

$$\Pr[Z^{(1)} \leq z] = \exp(-T z^{-\theta}),$$

the type II extreme value (Fréchet) distribution. Letting $z$ approach zero, as we do throughout this paper, this distribution is defined over all positive values of $z$.

\(^{10}\)In the Ricardian model of Eaton and Kortum (2002), all technologies in this sequence would be used to produce the same good $j$ so that if country $i$ produces good $j$, it uses $Z_{i}^{(1)}$, with all the rest irrelevant. The same is true of production in Bernard, Eaton, Jensen, and Kortum (2003), although $Z_{i}^{(2)}$ can be relevant in determining the price of good $j$. In each model, as in Dornbusch, Fischer, and Samuelson (1977), the space
4.2 Costs

We introduce impediments to trade in a standard way: Selling a unit of a good to market \( n \) from source \( i \) requires exporting \( d_{ni} \geq 1 \) units, where we set \( d_{ii} = 1 \) for all \( i \). It also requires hiring a fixed number \( F_n \) workers in market \( n \), which we allow to vary by \( n \) but, for simplicity, keep independent of \( i \).\(^{11}\)

We denote the wage in country \( i \) as \( w_i \). Then, a potential producer from country \( i \) with efficiency \( Z_i \) can sell in country \( n \) at a unit cost:

\[
C_{ni} = \frac{w_id_{ni}}{Z_i}.
\]

4.2.1 Continuum Case

Under the continuum specification (2), the measure of firms from country \( i \) that can sell in country \( n \) at unit cost \( C_{ni} \leq c \) is:

\[
\mu_{ni}^C(c) = \Phi_{ni} c^\theta,
\]

where:

\[
\Phi_{ni} = T_i(w_id_{ni})^{-\theta}.
\]

of goods is \( j \in [0,1] \). In our finite-firm model here, as in models of monopolistic competition, each technology \( Z_i^{(1)}, Z_i^{(2)}, Z_i^{(3)}, \ldots \) produces a unique good. How far up the list to go is determined (endogenously) by entry costs.

\(^{11}\)As we discuss subsequently, our data handle a cost that is common across sources with relative equanimity but balk at the imposition of an entry cost that is common across destinations. Because assuming a cost that is the same for all entrants in a market yields some simplification, we take that route. Chaney (2008) and EKK (2011) showed how to relax it.
Summing across sources $i = 1, ..., N$, the measure of firms from anywhere that can sell in $n$ at unit cost $c$ or less is:

$$
\mu_n^C(c) = \sum_{i=1}^{N} \mu_{ni}^C(c) = \Phi_n c^\theta
$$

where:

$$
\Phi_n = \sum_{i=1}^{N} \Phi_{ni}.
$$

(4)

Among firms with unit cost $C_n \leq c$, the fraction from country $i$ is:

$$
\pi_{ni} = \frac{\Phi_{ni}}{\Phi_n}
$$

(5)

regardless of $c$.

4.2.2 Finite-Firm Case

With only an integer number of firms we can associate each technology $Z_i^{(k)}$ in market $i$ with a unit cost of delivering in market $n$ of

$$
C_{ni}^{(k)} = w_i d_{ni} / Z_i^{(k)},
$$

so that $C_{ni}^{(1)} < C_{ni}^{(2)} < C_{ni}^{(3)} < ...$. An implication of this connection between costs and efficiency is that the number of firms from country $i$ that can sell in country $n$ at a cost $C \leq c$ is the realization of a Poisson random variable with parameter $\mu_{ni}^C(c) = \Phi_{ni} c^\theta$ (instead of a measure $\mu_{ni}^C(c)$). Furthermore, the total number of firms that could sell in $n$ at a cost $C \leq c$ is the realization of a Poisson random variable with parameter $\mu_n^C(c) = \Phi_n c^\theta$ (instead of a measure $\mu_n^C(c)$) where $\Phi_{ni}$ and $\Phi_n$ are still given by (3) and (4).

We can rank these firms according to their unit costs in $n$ irrespective of their source $C_n^{(1)} < C_n^{(2)} < C_n^{(3)} < ...$. To keep track of the source, we can define an indicator $I_{ni}^{(k)}$ to
equal 1 if the kth lowest-cost firm in n is from i (and 0 otherwise). Properties of the Poisson distribution imply:

$$\Pr \left[ I_{ni}^{(k)} = 1 \right] = \pi_{ni},$$

where $\pi_{ni}$ is defined in (5). The probability that the firm is from i is independent of its rank k in country n or its unit cost there, $C_n^{(k)}$. Unlike the continuum model, $\pi_{ni}$ is now the expected fraction of firms from i selling in n, rather than the realized fraction.

4.3 Entry

To close the model, we specify total spending in a market as $X_n$, and make the standard assumption that demand derives from an aggregator with a constant elasticity of substitution $\sigma > 1$.

Under these assumptions, a firm selling in market n with a unit cost $C$ charging a price $p$ makes a profit in that market, gross of the entry cost $E_n = w_n F_n$, of:

$$\Pi_n(p, C) = \left( 1 - \frac{C}{P_n} \right) \left( \frac{p}{P_n} \right)^{-(\sigma - 1)} X_n,$$

where $P_n$ is the price index in country n.

4.3.1 Continuum Case

In the case of a continuum of firms, each firm – no matter how efficient – has no effect on the overall price index $P_n$. It therefore sets a price $p_n(C)$ to maximize (6) taking $P_n$ as given, thereby choosing the standard Dixit-Stiglitz markup:

$$p_n(C) = \bar{m} C,$$
where:

\[ \bar{m} = \frac{\sigma}{\sigma - 1}. \]

Variable profit is decreasing in unit cost \( C \). Hence, firms enter market \( n \) up to the point at which their unit cost implies zero profit, net of the fixed entry cost, at a cost threshold \( \bar{c}_n \) satisfying:

\[ \left( \frac{m c_n}{P_n} \right)^{-(\sigma - 1)} \frac{X_n}{\sigma} = E_n. \]  \( (7) \)

The resulting price index is:

\[ P_n = \left[ \int_{0}^{c_n} (mc)^{-(\sigma - 1)} d\mu^C(c) \right]^{-1/(\sigma - 1)}. \]  \( (8) \)

Under the restriction that

\[ \theta > \sigma - 1 \]  \( (9) \)

Equations (7) and (8) together deliver nice analytic expressions for the price index:

\[ P_n = \bar{m} \left[ \frac{\theta}{\theta - (\sigma - 1)} \right]^{-1/\theta} \left( \frac{X_n}{\sigma E_n} \right)^{-[\theta - (\sigma - 1)]/[\theta(\sigma - 1)]} \Phi_n^{-1/\theta} \]

and cutoff:

\[ \bar{c}_n = \left[ \frac{\theta}{\theta - (\sigma - 1)} \right]^{-1/\theta} \left( \frac{X_n}{\sigma E_n} \right)^{1/\theta} \Phi_n^{-1/\theta}. \]

Without the restriction (9), however, the price index and cutoff are undefined. The reason is that technological heterogeneity and the elasticity of substitution are so large that buyers achieve zero cost by squeezing all of their spending into the lower tail of the cost distribution. Hence, it is standard in models with a continuum of goods to impose a restriction like (9).
In the continuum model, the firm sales distribution is Pareto with parameter $\theta/(\sigma - 1)$:\textsuperscript{12}

$$
\Pr \left[ X_n(C) \geq x \mid C \leq \tau_n \right] = \left( \frac{x}{\sigma E_n} \right)^{-\theta/(\sigma-1)}. \tag{10}
$$

Restriction (9) prevents this parameter from falling to 1 or below. Hence, the model cannot predict a highly skewed sales distribution without wandering into “forbidden” territory.

### 4.3.2 Finite-Firm Case

With only an integer number of firms, the restriction (9) is not needed because at no point do we integrate over the distribution of prices. Solving for the equilibrium is less straightforward, however. In the continuum model, an individual firm (of measure zero) naturally takes aggregate spending $X_n$, the wage $w_n$, and the price index $P_n$ as given in deciding what price to charge and whether to enter.

So as not to introduce too many complications into our finite-firm case at once, we continue to assume that firms take expenditure $X_n$ and the wage $w_n$ as given but incorporate the effect

\textsuperscript{12}The sales of a firm with cost $C \leq \tau_n$ are:

$$
X_n(C) = \left( \frac{mC}{P_n} \right)^{-(\sigma-1)} X_n,
$$

whereas the distribution of costs for such firms is

$$
\Pr \left[ C \leq c \mid C \leq \tau_n \right] = \frac{\mu_n^C(c)}{\mu_n^C(\tau_n)} = \left( \frac{c}{\tau_n} \right)^{\theta}.
$$

Combining these results using (7) yields (10). The expected sales of a firm in market $n$ are:

$$
\bar{X}_n = \int_{\sigma E_n}^{\infty} x \frac{\theta}{\sigma - 1} x^{\theta/(\sigma-1) - 1} (\sigma E_n)^{\theta/(\sigma-1)} dx
$$

$$
= \frac{\theta \sigma E_n}{\theta - (\sigma - 1)},
$$

which is finite only under the parameter restriction (9).
of their decisions on the price index $P_n$.\textsuperscript{13}

We treat equilibrium in any market as determined in two stages. In stage two, the number of firms $K_n$ entering into each market is given. The firms present in each market engage in Bertrand competition. This competition establishes a price associated with each unit cost $C$, denoted by $p_n(C)$.\textsuperscript{14} Gross profit in market $n$ of a firm with unit cost $C$ is:

$$\Pi_n(C) = \left[1 - \frac{C}{p_n(C)}\right]\left(\frac{p_n(C)}{P_n}\right)^{-(\sigma - 1)}X_n,$$

where now the price index is:

$$P_n = \left(\sum_{k=1}^{\infty} [p_n(C_n^{(k)})]^{-\sigma}I_n^{(k)}\right)^{-1/(\sigma - 1)}$$

where $I_n^{(k)} = 1$ if the firm with the $k$th lowest unit cost enters and $I_n^{(k)} = 0$ otherwise. Hence,

$$\sum_{k=1}^{\infty} I_n^{(k)} = K_n.$$

\textsuperscript{13}A huge benefit of treating $X_n$ and $w_n$ as unaffected by firms’ entry and price decisions is that we can separately analyze equilibrium in each market. Otherwise, a pricing or entry decision in any market would affect sales and wages in every country of the world, making the equilibrium difficult to compute. Various assumptions can justify our treatment of $X_n$ and $w_n$ as exogenous to the entry decision, all of them inelegant. One assumption is that wages are determined by trade in a different sector; a second is that profits are all spent on output from a different sector. We then can set $X_n = \alpha w_n L_n$ where $L_n$ is the labor force in country $n$ and $\alpha$ is the Cobb-Douglas share of manufactures in workers’ spending. The first assumption has a tradition in this literature, being a case considered in Eaton and Kortum (2002); it also appears in Chaney (2008) and Melitz and Ottaviano (2008). The second assumption resembles that of the “absentee landlord” sometimes posited in the economic geography literature. We hope that future research explores the implications of more attractive assumptions, but we do not expect results to differ much from those we report.

\textsuperscript{14}In fact, the price chosen by each firm in the Bertrand equilibrium in market $n$ depends on the unit costs of all firms present. We list only the firm’s own unit cost $C$ as an argument of $p_n$ because two firms that happened to have the same $C$, a probability zero event, would charge the same price $p_n(C)$.  

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We consider a situation in which \( f^{(k)}_n = 1 \) for \( k \leq K_n \) and 0 otherwise, giving the price index:

\[
P^{K_n}_n = \left( \frac{1}{\sum_{k=1}^{K_n} [p^{K_n}_n (C^{(k)}_n)]^{-(\sigma-1)}} \right)^{-1/(\sigma-1)}
\]

where the \( K_n \) superscript denotes the dependence of prices on the number of entrants. The corresponding gross profit of the \( k \)th lowest-cost firm, with \( k \leq K_n \), is:

\[
\Pi^{K_n}_n (C^{(k)}_n) = \left[ 1 - \frac{C^{(k)}_n}{p^{K_n}_n (C^{(k)}_n)} \right] \left( \frac{p^{K_n}_n (C^{(k)}_n)}{P^{K_n}_n} \right)^{-(\sigma-1)} X_n
\]

The following (unsurprising) result, which we call profit monotonicity, is useful in determining entry:\(^{15}\)

\[
\Pi^{K+1}_n (C^{(K+1)}_n) \leq \Pi^K_n (C^{(K)}_n)
\]

\(^{15}\)An outline of the proof is as follows. First, we note that in any Bertrand equilibrium:

\[
\Pi^{K+1}_n (C^{(K+1)}_n) \leq \Pi^{K+1}_n (C^{(K)}_n)
\]

The reason is that the firm with unit cost \( C^{(K)}_n \) could always earn a higher profit than the firm with cost \( C^{(K+1)}_n \) simply by charging the same price as that firm (hence, selling the same quantity at a lower cost).

Second, we note that removing the firm with unit cost \( C^{(K+1)}_n \) raises the profit of all remaining firms. We can consider the profit of the \( k \)'th firm as a function of the price of each entrant (not necessarily its equilibrium price), which we denote by \( \Pi^{(k)}_n (p^{(1)}_n, p^{(2)}_n, ..., p^{(K+1)}_n) \). Removing firm \( K + 1 \) is a special case of raising its price arbitrarily. That the profit of all remaining firms rises follows from the fact that both:

\[
\frac{\partial \Pi^{(k)}_n (p^{(k)}_n)}{\partial p^{(k)}_n} \geq 0
\]

and

\[
\frac{\partial^2 \Pi^{(k)}_n (p^{(k)}_n)}{\partial p^{(k)}_n \partial p^{(k)}_n} \geq 0
\]

for \( k' \neq k \). The first inequality implies that a higher price on the part of a rival raises profit and the second implies that a higher price by a rival raises the price charged by any other firm. Hence, a higher price from the firm with unit cost \( C^{(K+1)}_n \) causes every other firm to raise its price, which raises the profit of all remaining...
In the first stage, firms decide whether to enter each market. To avoid uninteresting multiple equilibria, we assume that they make their entry decisions sequentially, starting with the firm with the lowest unit cost $C_n^{(1)}$, followed by the firm with unit cost $C_n^{(2)}$, and so on.\footnote{With a discrete number of firms, a possible outcome is entry by one or more less-efficient firms blocking a more-efficient firm from entering. With a continuum of firms, this possibility does not arise because no firm has any effect on the aggregate outcome.}

When making its decision to enter, each firm anticipates perfectly what its profit would be in the subsequent second-stage Bertrand equilibrium. An immediate implication of profit monotonicity (12) is that the two conditions:

$$\Pi_n^{K_n}(C_n^{(K_n)}) \geq E_n$$

and:

$$\Pi_n^{K_n+1}(C_n^{(K_n+1)}) < E_n.$$ 

determine $K_n$. Firms will enter up to the point at which the firm with unit cost $C_n^{(K_n+1)}$ would not be able to cover its entry cost.\footnote{To avoid the outcome $K_n = 0$ (in which case we could not have taken $X_n$ as given), we assume $X_n \geq E_n$.}

We have now completed the statement of the finite-firm model. With a finite number of firms, the full set of parameters $\theta, \sigma, T, d, X_n, w_n$ are not enough to determine the firms, including that of the firm with unit cost $C_n^{(K)}$. Letting $C_n^{(K+1)}$ rise without bound:

$$\Pi_n^{K+1}(C_n^{(K)}) \leq \Pi_n^K(C_n^{(K)}).$$

Combining these two profit inequalities delivers the profit-monotonicity result (12).

A possible outcome is $K_n = 1$, in which case the monopolist charges a price approaching infinity, supplies a quantity approaching 0, and obtains gross profit of $\Pi_n^{1}(C_n^{(1)}) = X_n$. In subsequent sections, we fit the model to data and simulate entry. With realistic parameter values, the monopoly outcome never comes close to happening.
equilibrium of the model. We also need the realizations of the technologies \( Z_i^{(k)} \) in each source \( i \) determining ordered costs \( C_n^{(k)} \) in each destination \( n \). The equilibrium in each destination determines overall entry \( K_n \) and the price level \( P_n \), as well as entry by individual firms, as indicated by \( I_{ni}^{(k)} \), and their sales there.\(^{18}\)

\[
X_n^{(k)} = \left( \frac{P_n K_n C_n^{(k)}}{P_n K_n} \right)^{-(\sigma-1)} X_n.
\]  

(13)

The total number of firms from \( i \) entering \( n \) is thus:

\[
K_{ni} = \sum_{k=1}^{K_n} I_{ni}^{(k)} \quad (14)
\]

and their total sales:

\[
X_{ni} = \sum_{k=1}^{K_n} I_{ni}^{(k)} X_n^{(k)}. \quad (15)
\]

We conclude with three implications of the discrete model important for the quantitative analysis that follows:

1. The probability \( \pi_{ni} \) that a firm selling in country \( n \) is from country \( i \) is independent of its rank \( k \) or its unit cost \( C_n^{(k)} \) in market \( n \), and hence, of its sales there, \( X_n^{(k)} \).

2. Because the number of firms \( K_{ni} \) from \( i \) selling in \( n \) is determined by a finite number of Bernoulli trials, zero is a possibility.

3. Unlike the continuum model, we need no restrictions on \( \theta \) other than \( \theta > 0 \).

\(^{18}\)The definition of the price index ensures that the sales of each entrant sum to total spending:

\[
\sum_{k=1}^{K_n} X_n^{(k)} = X_n.
\]
5 Quantification

Our goal is to determine whether our finite-firm model can capture patterns of trade at both the aggregate and firm levels. We proceed in the following five steps, which culminate in a fully parameterized version of the finite-firm model:

1. We specify a gravity equation consistent with our firm-level model, which we estimate using data on bilateral trade in manufactures. This step provides estimates of the market-entry probability \( \pi_{ni} \) given in (5).

2. We use firm-level data to extract an estimate of mean sales per firm \( \bar{X}_n \) in each market \( n \), from which we can estimate total entry \( K_n = X_n/\bar{X}_n \). Our estimates of \( \pi_{ni} \) and \( K_n \) allow us to calculate the probability of zero exports from each source \( i \) to each destination \( n \).

3. We construct cost draws that allow us to simulate an entire matrix of entry by firms from each source \( i \) in each destination \( n \).

4. We use these cost draws to calculate the Bertrand equilibrium in each destination. This calculation yields the sales distribution of firms across markets.

5. We infer entry costs \( E_n \), which completes the parameterization.

At the completion of the fifth step, we are prepared to perform the counterfactuals in the subsequent section.
5.1 The Gravity Equation

The gravity equation has a long and successful history of capturing empirically how much one country sells to another. A standard formulation is:

\[ X_{ni} = \frac{Y_i X_n}{k_{ni}} \]

where \( Y_i \) is production in the exporting country \( i \) and \( k_{ni} \) is the distance from \( i \) to \( n \). Although there has been much progress in deriving such an equation (suitably modified) from theories of trade, an important remaining issue in taking this equation to data is the specification of the error term.

Our finite-firm model implies that randomness can emerge from two sources. First, given the provenance of firms that have entered a market, firms from some source might have drawn particularly low \( C \)s and thus sell more. Second, given the expectation \( \pi_{ni} \) that a firm in \( n \) is from \( i \), firms from \( i \) might have had particularly lucky rolls of the die and therefore have a larger than expected presence in \( n \).

To capture these two sources of error, we divide each side of (15) by total expenditure on manufactures (i.e., absorption) in market \( n \) and take the expectations of each side to obtain:

\[ E \left[ \frac{X_{ni}}{X_n} \right] = E \left[ \sum_{k=1}^{K_n} I_{ni}(k) X_n^{(k)} \right] = E \left[ \sum_{k=1}^{K_n} E \left[ I_{ni}(k) | X_n^{(k)} \right] \frac{X_n^{(k)}}{X_n} \right]. \]

The first implication of our model enumerated at the end of Section 4 – that the probability of a firm being from \( i \) is independent of \( k \) and \( X_n^{(k)} \) – allows us to write this expression as:

\[ E \left[ \frac{X_{ni}}{X_n} \right] = \pi_{ni} E \left[ \sum_{k=1}^{K_n} \frac{X_n^{(k)}}{X_n} \right]. \]

Because the remaining summation is over all firms selling in \( n \), it is identically 1 (and, hence,
its expectation is also). We have simply:

$$E \left[ \frac{X_{ni}}{X_n} \right] = \pi_{ni},$$

(16)

The expectation of country \(i\)'s market share in \(n\) is the probability that any particular firm in \(n\) is from \(i\).

We can use equations (3), (4), and (5) to connect \(\pi_{ni}\) to our model and write it as a multinomial logit function:

$$E \left[ \frac{X_{ni}}{X_n} \right] = \pi_{ni} = \frac{\exp (\ln T_i - \theta \ln w_i - \theta \ln d_{ni})}{\sum_{t=1}^{N} \exp (\ln T_t - \theta \ln w_t - \theta \ln d_{nt})}.$$  

(17)

Equation (17) is the basis of our gravity estimation, with \(X_{ni}/X_n\) measured by actual trade shares. We parameterize the right-hand side of (17) as follows. We set:

$$S_i = \ln T_i - \theta \ln w_i,$$

capturing source-specific determinants of trade as a fixed effect. We use geographical measures to capture the costs of exporting from \(i\) to \(n\). Specifically, for \(i \neq n\), we set:

$$-\theta \ln d_{ni} = m_n + g'_{ni} \alpha + \ln \nu_{ni}.$$  

Here, \(m_n\) is a destination fixed effect capturing differences in openness to imports and \(g_{ni}\) is a vector of observables potentially raising trade costs (in our case, the log of distance and indicators for lack of a common border, lack of a common language, lack of a common legal origin, lack of a common colonizer, and lack of colonial ties).\(^{19}\) Because these indicators are unlikely to reflect all aspects of trade costs, we also introduce an unobservable component of trade costs \(\nu_{ni}\) (with \(\nu_{nn} = 1\) because \(d_{nn} = 1\)).

\(^{19}\)These variables are from Head, Mayer, and Ries (2010), available on the CEPII web site.
We now have an additional source of randomness. The connection between observables and \( \pi_{ni} \) is itself random.\(^{20}\)

To obtain an expression suitable for estimation, we define:

\[
\varphi_{ni} = \begin{cases} 
\exp(S_i + m_n + g'_ni\alpha) & i \neq n \\
\exp(S_n) & i = n
\end{cases}
\]

and:

\[
\Lambda_{ni} = \frac{\varphi_{ni}}{\sum_l \varphi_{nl}}.
\]

We then can write:

\[
\pi_{ni} = \frac{\varphi_{ni} \nu_{ni}}{\sum_l \varphi_{nl} \nu_{nl}}.
\]

To apply a standard estimation procedure, \( \nu_{ni} \) must have the property that:

\[
E[\pi_{ni} | \Lambda] = E\left[ \frac{\varphi_{ni} \nu_{ni}}{\sum_l \varphi_{nl} \nu_{nl}} \right] = \Lambda_{ni},
\]

where conditioning on the observables \( \Lambda \) means that the \( \nu_{ni} \) are treated as random variables. Thus, constructing \( \Lambda_{ni} \) from the true parameters and observables delivers an unbiased predictor of \( \pi_{ni} \).\(^{21}\)

\(^{20}\)An analogy is the likelihood of a 3 from a roll of a die with unknown bias. There is randomness due not only to multinomial sampling but also to the uncertainty of the bias. Our error term \( \nu_{ni} \) introduces such bias.

We assume that the distribution of \( \nu_{ni} \) is such that there is no ex-ante bias.

\(^{21}\)One way to construct \( \nu_{ni} \) that satisfy (19) is based on the gamma distribution. A random variable \( X \) is distributed Gamma\((a, b)\) (with mean \( ab \) and variance \( ab^2 \)) if its distribution is:

\[
\Pr[X \leq x] = \frac{1}{\Gamma(a)} \int_0^{x/b} t^{a-1} \exp(-t) dt
\]

where

\[
\Gamma(a) = \int_0^\infty t^{a-1} \exp(-t) dt
\]

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Putting together these sources of error, the moment conditions we use for our estimation are:

\[
E \left[ \frac{X_{ni}}{X_n} \mid \Lambda \right] = \Lambda_{ni} = \begin{cases} 
\frac{\exp(S_i + m_n + g'_{ni} \alpha)}{\exp(S_n) + \sum_{l \neq n} \exp(S_i + m_n + g'_{ni} \alpha)} & i \neq n \\
\frac{\exp(S_n)}{\exp(S_n) + \sum_{l \neq n} \exp(S_i + m_n + g'_{ni} \alpha)} & i = n 
\end{cases}
\]

These conditions are nonlinear in the parameters that we need to estimate. However, because the \( \Lambda_{ni} \) sum to 1 across all sources \( i \) (for any \( n \)), the parameters can be estimated quite easily by multinomial pseudo-maximum likelihood (PML), as described in Gouriéroux, Monfort, and Trognon (1984). We apply this estimator to our data on bilateral trade \( X_{ni} \) between 92 is the complete gamma function. We let \( \nu_{ni} = (V_{ni}/V_{nn}) \) so that

\[
\pi_{ni} = \frac{\varphi_{ni} \nu_{ni}}{\sum_l \varphi_{nl} \nu_{nl}} = \frac{\Lambda_{ni} V_{ni}}{\sum_l \Lambda_{nl} V_{nl}}
\]

and assume that \( V_{ni} \) is distributed \( \text{Gamma} \left( \frac{\Lambda_{ni}}{\eta^2}, \frac{\eta^2}{\Lambda_{ni}} \right) \). From the properties of the gamma distribution, we have:

\[
\Lambda_{ni} V_{ni} \approx \text{Gamma} \left( \frac{\Lambda_{ni}}{\eta^2}, \frac{\eta^2}{\Lambda_{ni}} \right),
\]

and

\[
\sum_i \Lambda_{ni} V_{ni} \approx \text{Gamma} \left( \frac{1}{\eta^2}, \frac{\eta^2}{\Lambda_{ni}} \right).
\]

The vector of \( \pi_{ni} \)'s is therefore distributed:

\[
(\pi_{n1}, \pi_{n2}, \pi_{n3}, ..., \pi_{nN}) \approx \text{Dirichlet} \left( \frac{\Lambda_{n1}}{\eta^2}, \frac{\Lambda_{n2}}{\eta^2}, \frac{\Lambda_{n3}}{\eta^2}, ..., \frac{\Lambda_{nN}}{\eta^2} \right)
\]

with mean:

\[
E [\pi_{ni}] = \frac{\Lambda_{ni}}{\sum_i \Lambda_{ni} / \eta^2} = \Lambda_{ni}
\]

so that (19) is satisfied. The variance is given by:

\[
\text{Var}[\pi_{ni}] = \frac{\eta^2}{\eta^2 + 1} \Lambda_{ni} (1 - \Lambda_{ni})
\]

The derivation follows the derivation of the random effects negative binomial model in Hausman, Hall, and Griliches (1984).
countries, where we include home sales, $X_{nn}$, for $i = n$.\footnote{In the continuum model of Eaton and Kortum (2002), instead of (16), we would have:

$$\frac{X_{ni}}{X_n} = \pi_{ni}$$

(without the expectation). In that case, we can write (18) as:

$$\frac{X_{ni}}{X_n} = \frac{\phi_{ni} \nu_{ni}}{\sum_l \phi_{nl} \nu_{nl}}.$$}

The results appear in the last column of Table 3 showing the coefficients $\hat{\alpha}$ on the gravity variables. In line with most gravity equations specified in a more conventional form, the coefficient on the log of distance is estimated to be near -1.\footnote{Chaney (2011) provided a theoretical explanation for this regularity.} All of the other geography variables have the expected negative effect on trade as well. For comparison, the first two columns of the table show estimates of the same parameters obtained by approaches that have been used in earlier work.\footnote{The first column follows Eaton and Kortum (2002), in which the dependent variable was $\ln(X_{ni}/X_{nn})$. Although this approach can be estimated using OLS, it requires dropping observations with zero trade. The middle column follows Santos Silva and Tenreyro (2006), applying Poisson PML, with the dependent variable $X_{ni}$. Neither of these other approaches is fully consistent with our finite-firm model.} Focusing on the coefficient of log distance, our results are in between what is delivered by running a regression in logs, dropping observations with zero trade and applying Poisson probability weighted maximum likelihood (PML).\footnote{Focus on the first column follows Eaton and Kortum (2002), in which the dependent variable was ln($X_{ni}/X_{nn}$). Although this approach can be estimated using OLS, it requires dropping observations with zero trade. The middle column follows Santos Silva and Tenreyro (2006), applying Poisson PML, with the dependent variable $X_{ni}$. Neither of these other approaches is fully consistent with our finite-firm model. To tackle the zeros problem, the Poisson PML approach taken by Santos Silva and Tenreyro (2006) is used.}
trade flows, and the one delivered by Poisson PML.²⁵

Table 3. Bilateral trade regressions

<table>
<thead>
<tr>
<th></th>
<th>OLS</th>
<th>Poisson</th>
<th>Multinomial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>-1.418***</td>
<td>-0.699***</td>
<td>-1.072***</td>
</tr>
<tr>
<td></td>
<td>(0.0379)</td>
<td>(0.0444)</td>
<td>(0.0511)</td>
</tr>
<tr>
<td>Lack of Contiguity</td>
<td>-0.442**</td>
<td>-0.694***</td>
<td>-0.370**</td>
</tr>
<tr>
<td></td>
<td>(0.156)</td>
<td>(0.181)</td>
<td>(0.136)</td>
</tr>
<tr>
<td>Lack of Common Language</td>
<td>-0.686***</td>
<td>0.121</td>
<td>-0.511***</td>
</tr>
<tr>
<td></td>
<td>(0.0808)</td>
<td>(0.131)</td>
<td>(0.106)</td>
</tr>
<tr>
<td>Lack of Common Legal Origin</td>
<td>-0.184**</td>
<td>-0.281***</td>
<td>-0.133</td>
</tr>
<tr>
<td></td>
<td>(0.0593)</td>
<td>(0.0778)</td>
<td>(0.0721)</td>
</tr>
<tr>
<td>Lack of Common Colonizer</td>
<td>-0.212</td>
<td>0.222</td>
<td>-0.306</td>
</tr>
<tr>
<td></td>
<td>(0.146)</td>
<td>(0.199)</td>
<td>(0.204)</td>
</tr>
<tr>
<td>Lack of Colonial Ties</td>
<td>-0.684***</td>
<td>0.226</td>
<td>-0.953***</td>
</tr>
<tr>
<td></td>
<td>(0.126)</td>
<td>(0.122)</td>
<td>(0.139)</td>
</tr>
<tr>
<td>Adjusted R sq.</td>
<td>0.968</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo R sq.</td>
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<td>0.993</td>
<td>0.563</td>
</tr>
<tr>
<td>Number of observations</td>
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<td>8464</td>
<td>8464</td>
</tr>
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</table>

Standard errors in parentheses
* p < 0.05, ** p < 0.01, *** p < 0.001

²⁵One explanation for the different results is that the three estimation approaches apply different penalties to deviations between model and data for large and small trade flows. By taking logs, the approach in the first column treats proportional deviations as equally likely across all observations. At the other extreme, Poisson PML applies a much greater penalty to a given proportional deviation in a large trade flow than in a small one (because a proportional deviation from the mean becomes less likely for a Poisson distributed random variable as the mean is increased). Our current approach is between the two. Our dependent variable normalizes bilateral trade flows by the importers’ total absorption, thus eliminating different penalties for proportional deviations across large and small trade flows, to the extent that they vary with the size of the destination. Yet, our approach is more like Poisson PML in that that proportional deviations from a large exporting country are much less likely than for a small exporter.
We use our estimates of the gravity equation to calculate
\[
\hat{\pi}_{ni} = \frac{\hat{\varphi}_{ni}}{\sum_{k=1}^{N} \hat{\varphi}_{nk}}
\]
using the estimated coefficients \(\hat{\varphi}_i, \hat{\varphi}_m,\) and \(\hat{\alpha}\) and data on source and geography. These estimated entry probabilities \(\hat{\pi}_{ni}\) have the desirable properties of lying strictly between 0 and 1, even though they are based on trade shares that are frequently zero in the data. Thus, they predict a positive trade flow even when none is observed in the data.

### 5.2 Mean Sales per Firm

Because we assume that the cost of entry \(E_n\) does not vary with the source country \(i\), our model implies that in expectation, mean sales in a destination should be the same for all \(i\):
\[
E[X_{ni}] = E[X_n].
\]

We can exploit this restriction to estimate mean sales \(\bar{X}_n\) of firms in a market using our limited firm-level data. To do so, we pool our data on sales across the four source countries (i.e., Brazil, Denmark, France, and Uruguay). As described previously, we restrict ourselves to destinations for which we have data from at least two sources.\(^{26}\) Our estimate of mean sales is simply:
\[
\hat{X}_n = \frac{\sum_{i \in \Omega} K_{ni} X_{ni}}{\sum_{i' \in \Omega} K_{ni'}},
\]

\(^{26}\)We drop the home-country observations (when available) because the universe of firms selling in the home market typically is measured very differently. The customs data indicate the number of exporters and their sales in a foreign market. The total number of active firms in a country is more difficult to determine because many may not be counted. Because there are so few exporters from Uruguay, we merge the data for that country in 1992 and 1993.

29
where $\Omega_n$ is the set of source countries for which we have firm-level data on exports to destination $n$. The results are shown in Table 4.\footnote{To gauge the plausibility of our restriction that $E_{ni} = E_n$, we examine whether mean sales $X_{ni}$ of our four source countries (which are diverse in economic size and development) differ among each other in a systematic way. We run a weighted OLS regression of the unbalanced panel $X_{ni}$ on a full set of destination-country effects and source-country effects. (The weights, $K_{ni}/(\hat{X}_n)^2$, correct for the fact that the observations are averages over different numbers of firms, and destination countries differ in mean sales.) Table 5 reports the source-specific intercepts relative to France, which is normalized to zero. The estimates imply modest variation across sources, with Brazil’s mean sales about $70,000$ higher than in France, whereas Denmark’s and Uruguay’s mean sales are about $25,000$ lower. Although we can easily reject the joint hypothesis of equal mean sales by source, the small magnitude of the deviations suggests that we will not do great violence to the data by simply ignoring them.} Mean sales range from $\$47,000$ in the Central African Republic to $\$1.6$ million in the United States, with an elasticity with respect to total expenditure $X_n$ of 0.33.\footnote{The slope in Figure 1 implies that exports per firm rise with a country’s total exports with an elasticity of 0.29. As is known from the gravity literature, total exports increase with destination expenditures with an elasticity close to 1, so the two results are very much in line.}

Because we treat expenditures on manufactures in a market $X_n$ as fixed at its actual value, our estimate $\hat{X}_n$ provides a way to infer the number of firms $\hat{K}_n = X_n/\hat{X}_n$ that sell there. Simulating the model to generate $K_n = \hat{K}_n$, our simulation will automatically match our estimate of mean sales per firm.

With $\hat{\pi}_{ni}$ and $\hat{K}_n$ in hand, we can calculate the likelihood of a zero bilateral export as follows. Without the trade cost shocks $\nu_{ni}$, we can use the binomial distribution to obtain an expression for the probability of a zero:

$$\Pr[K_{ni} = 0] = (1 - \pi_{ni})^{K_n}$$

\hspace{1cm} (21)
Table 4. Mean sales per firm

<table>
<thead>
<tr>
<th>Destination country</th>
<th>No. of source countries</th>
<th>Mean sales per firm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>2</td>
<td>0.426</td>
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<tr>
<td>Angola</td>
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<td>0.272</td>
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<td>Argentina</td>
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<td>0.638</td>
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<tr>
<td>Australia</td>
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<tr>
<td>Austria</td>
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<td>0.334</td>
</tr>
<tr>
<td>Bangladesh</td>
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<td>0.391</td>
</tr>
<tr>
<td>Benin</td>
<td>2</td>
<td>0.079</td>
</tr>
<tr>
<td>Bolivia</td>
<td>3</td>
<td>0.174</td>
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<tr>
<td>Brazil</td>
<td>3</td>
<td>0.493</td>
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<tr>
<td>Bulgaria</td>
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<td>0.211</td>
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<tr>
<td>Burkina Faso</td>
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<td>0.065</td>
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<td>Burundi</td>
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<td>0.065</td>
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<tr>
<td>Cameroon</td>
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<td>0.096</td>
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<td>Canada</td>
<td>4</td>
<td>0.301</td>
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<tr>
<td>Central African Republic</td>
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<td>0.047</td>
</tr>
<tr>
<td>Chad</td>
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<tr>
<td>Chile</td>
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<tr>
<td>China</td>
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<td>1.811</td>
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<td>Costa Rica</td>
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</tr>
<tr>
<td>Kuwait</td>
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<td>0.256</td>
</tr>
</tbody>
</table>

continued next page

31
<table>
<thead>
<tr>
<th>Destination country</th>
<th>No. of source countries</th>
<th>Mean sales per firm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madagascar</td>
<td>2</td>
<td>0.079</td>
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<td>Malawi</td>
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<td>Mauritius</td>
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Table 5. Source-country coefficients

<table>
<thead>
<tr>
<th></th>
<th>Mean sales*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>-0.0279 (0.0216)</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.0724** (0.0221)</td>
</tr>
<tr>
<td>Uruguay</td>
<td>-0.0265 (0.0680)</td>
</tr>
</tbody>
</table>

p-value for F test of joint significance 0.0050
Number of observations 282

Standard errors in parentheses
*OLS Regression also includes all destination country effects as independent variables
*p < 0.05, **p < 0.01, ***p < 0.001

which we evaluate at \( K_n = \hat{K}_n \) and \( \pi_{ni} = \hat{\pi}_{ni} \). Figure 2a is a histogram with the predicted probability of zero trade along the horizontal axis and the frequency of observations with that predicted probability on the vertical axis, for all country pairs in which \( X_{ni} = 0 \). (Figure 2b reports the corresponding histogram for pairs in which \( X_{ni} > 0 \).) Although we predict a low probability of zero trade when there in fact is trade (Figure 2b), we sometimes also predict a low probability of zero trade even when there is no trade (Figure 2a). Including trade-cost shocks helps to reduce the errors in Figure 2a.

29 We can also incorporate \( \nu_{nis} \) along the lines proposed in Footnote 16 as follows. Our assumptions there imply that the vector of \( \pi_{nis} \) for each destination \( n \) are distributed Dirichlet(\( \Lambda_{n1}/\eta^2, \Lambda_{n2}/\eta^2, \ldots, \Lambda_{nN}/\eta^2 \)). The corresponding marginal distribution for any source \( i \) is distributed Beta(\( \Lambda_{ni}/\eta^2, (1-\Lambda_{ni})/\eta^2 \)). The probability of a zero is then:

\[
\Pr[K_{ni} = 0] = \frac{\Gamma(1/\eta^2)}{\Gamma(\Lambda_{ni}/\eta^2)\Gamma((1-\Lambda_{ni})/\eta^2)} \int_0^1 (1-x)^{K_n}\ x^{(\Lambda_{ni}/\eta^2)-1}(1-x)^{(1-\Lambda_{ni})/\eta^2-1}dx
\]

whence we evaluate at \( K_n = \hat{K}_n \) and \( \Lambda_{ni} = \hat{\pi}_{ni} \) and \( \eta^2 = 0.0001 \) (the results deteriorate with larger values of \( \eta^2 \)).
Figure 2a. Probabilities of observing zero trade, given no trade

Figure 2b. Probabilities of observing zero trade, given positive trade
We can also use equation (21) to simulate the number of export destinations and import sources for each country (the actual values are shown in the last two columns of Table 1). The simulated average number of unidirectional trade links per country is 70.5 (from a maximum of 91), somewhat overpredicting the actual number. The simulations also fit the fact that the variance is higher across export destinations, 1,077, than across import sources, 48.6, although this difference is substantially magnified relative to the data. Figures 3a and 3b provide a more detailed comparison of the simulations and the data, plotting each against a country’s expenditure on manufactures, a convenient measure of country size. Whereas the model captures the basic pattern that trade links rise with country size, for small countries it typically undershoots the number of export destinations and overshoots the number of import sources.

Why is our model able to predict that zeros are so much more variable across export destinations than across importer sources? A reason is that a country’s success in penetrating a market as an exporter depends on the efficiency of its most efficient firm, generating enormous correlation

\[ \text{A simulation proceeds as follows, letting } q_{ni} \text{ denote the estimated value of (21). We draw } W_i \text{ independently for } i = 1, 2, ..., N \text{ from the uniform distribution on } [0,1]. \text{ We construct the indicator } \delta_{ni} = 1 \text{ if } W_i > q_{ni} \text{ and } \delta_{ni} = 0 \text{ otherwise. We count } i \text{’s export destinations as:} \]

\[ N^E(i) = \sum_{n \neq i} \delta_{ni} \]

and count n’s import sources as

\[ N^I(n) = \sum_{i \neq n} \delta_{ni}. \]

The results presented are based on averages from carrying out this simulation 1,000 times.
Figure 3a. Actual and Simulated Number of Destinations

Figure 3b. Actual and Simulated Number of Sources
across foreign markets in entry. Thus, two countries with the same geography and size likely would be very similar in terms of their ability to attract entry from other countries. However, the two countries would differ enormously in their ability to penetrate foreign markets if the lead firm in one was much more efficient than the lead firm in the other. Thus, the much greater variance in exporter zeros is consistent with the finite-firm model.

5.3 Simulating Unit Costs

An advantage of formulating the model in terms of an ordering of efficiencies and unit costs is that we can exploit properties of order statistics to simulate these objects. In particular, our model implies that the most efficient firm from each source \( i \) has an efficiency \( Z_{i}^{(1)} \) drawn from the Type II extreme-value (Fréchet) distribution:

\[
\Pr[Z_{i}^{(1)} \leq z] = e^{-T_i z^{-\theta}}.
\]

It follows that \( U_{i}^{(1)} = T_i \left(Z_{i}^{(1)}\right)^{-\theta} \) is distributed exponential, free of any parameters:

\[
\Pr\left[U_{i}^{(1)} \leq u\right] = 1 - e^{-u}.
\]

We can proceed up the ordered efficiencies, defining:

\[
U_{i}^{(k)} = T_i \left(Z_{i}^{(k)}\right)^{-\theta}
\]

for any \( k > 1 \). In Eaton and Kortum (2010), we show that the spacings in this sequence also have an exponential distribution:

\[
\Pr\left[U_{i}^{(k+1)} - U_{i}^{(k)} \leq u\right] = 1 - e^{-u}.
\]

For each source \( i \) we construct \( U_{i}^{(k)} \) for \( k \) up to \( K \) 3.2 million, much more than we ever need. The resulting normalized ordered costs (inversely related to efficiency) for each source \( i \) are
simply a random walk of length $\bar{K}$ with unit-exponential increments and an initial value drawn from a unit exponential.

We use these normalized ordered costs to construct ordered unit costs $C_{ni}^{(k)}$ of delivery to country $n$ by firms from $i$, invoking (22), (5), and (3):

$$C_{ni}^{(k)} = \frac{w_id_{ni}}{\left(U_i^{(k)}/T_i\right)^{1/\theta} \Phi_n \pi_{ni}} = \left(U_i^{(k)}/\Phi_n \pi_{ni}\right)^{1/\theta},$$

for $k = 1, 2, 3, ..., \bar{K}$. Estimates of $\pi_{ni}$ and $\theta$ are needed in this step. We use $\hat{\pi}_{ni}$ for $\pi_{ni}$ and set $\theta = 4.87$ from EKK (2011). 31 (The term $\Phi_n$ cancels out of the relevant formulas.)

In any particular destination $n$, we can combine all the $C_{ni}^{(k)}$ from each source $i$ and for all $k$ and then order them once again (without regard to source) to form:

$$C_n^{(1)} < C_n^{(2)} < C_n^{(3)} < ... < C_n^{(\bar{K}n)}$$

(This ordering is invariant to $\Phi_n$.) These ordered costs are the basis for calculating the Bertrand equilibrium in the next section. The source country $i$ of any firm is irrelevant for calculating the Bertrand equilibrium. We nevertheless keep track of the source $I_{ni}^{(k)}$ for each firm in order to calculate who sells where.

5.4 Simulating Sales

We can focus on a particular destination $n$ because the same routine applies to each market and our assumptions shut down any interactions among them. For a fixed $K_n$, all that is relevant for calculating the equilibrium in market $n$ are the $C_n^{(k)}$s and a value of $\sigma$. We start

31EKK’s (2011) estimate is based on productivity and sales data from French exporters. Simonovska and Waugh (2011) found a similar value (4.12) using international price-comparisons data.
with \( \sigma = 2.98 \) from EKK (2011). In the continuum case, our values of \( \theta \) and \( \sigma \) would imply that sales are distributed Pareto with parameter \( \theta / (\sigma - 1) = 2.46 \). We also try \( \sigma = 5.64 \) and \( \sigma = 7.09 \). In the continuum model, the implied parameters for the sales distribution would be 1.05 (with infinite variance) and 0.8 (with infinite mean and variance), respectively. For this last value, the continuum model would explode.

We solve for the Bertrand equilibrium prices \( p_n^{K_n} \left( C_n^{(k)} \right) \) in each country along with each firm’s market share:\(^{32}\)

\[
 s_n^{(k)} = \frac{\left[ p_n^{K_n} \left( C_n^{(k)} \right) \right]^{-(\sigma - 1)}}{\sum_{k=1}^{K_n} \left[ p_n^{K_n} \left( C_n^{(k)} \right) \right]^{-(\sigma - 1)}}. \tag{23}
\]

Our iterative numerical procedure exploits the condition for Bertrand-equilibrium markups given in Atkeson and Burstein (2008):

\[
m_n^{(k)} = \frac{p_n^{K_n} \left( C_n^{(k)} \right)}{C_n^{(k)}} = 1 + \frac{1}{(\sigma - 1)(1 - s_n^{(k)})}. \tag{24}
\]

One issue of interest is how much these markups \( m_n^{(k)} \) exceed the Dixit-Stiglitz markup \( \bar{m} = \sigma / (\sigma - 1) \). Figure 4 shows the simulated distribution of markups among the \( k = 1, \ldots, 10 \) largest firms across all markets (for \( \sigma = 5.64 \)). Even at the top 95th percentile, the markup

\(^{32}\)As mentioned previously, we can simulate costs only up to an unknown constant \( \Phi_n^{1/\theta} > 0 \). Inspection of (23) and (24) shows that multiplying all costs \( C_n^{(k)} \) by \( \Phi_n^{1/\theta} \) leaves \( s_n^{(k)} \) and \( m_n^{(k)} \) unchanged, with

\[
p_n^{K_n} (\Phi_n^{1/\theta} C_n^{(k)}) = \Phi_n^{1/\theta} p_n^{K_n} (C_n^{(k)}),
\]

for all \( k = 1, 2, \ldots, K_n \). As a consequence, sales \( X_n^{(k)} = s_n^{(k)} X_n \) and gross profits:

\[
\Pi_n^{K_n} (C_n^{(k)}) = (1 - 1/m_n^{(k)}) X_n^{(k)}
\]

are unchanged. Our solutions for what firms sell, their markups, and entry (discussed in Section 5.5) therefore are all invariant to \( \Phi_n \).
of the largest firm in a market is around 1.29, as compared with a Dixit-Stiglitz markup of 1.22. For lower-ranked firms the markup is only negligibly higher than the Dixit-Stiglitz markup. \(^{33}\)

We also can calculate the sales of each firm where it has entered as:

\[
X_{ni}^{(k)} = I_{ni}^{(k)} X_n^{(k)} = I_{ni}^{(k)} s_n^{(k)} X_n.
\]

From these simulated sales, we identify the top 10, 100, 1000, and 10,000 French exporters across all foreign markets. We then calculate the contribution of each group both to total French exports and to French exports in each foreign market. Table 6 shows the results.

\(^{33}\)We also calculated markups under Cournot competition. At the 95th percentile the markup of the largest firm is 1.45 and markup of the second largest is 1.30.
Table 6. Share of largest French exporters

<table>
<thead>
<tr>
<th></th>
<th>Average (across 10 simulations)</th>
<th>Standard deviation (across 10 simulations)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\sigma = 7.09)</td>
<td>(\sigma = 5.64)</td>
</tr>
<tr>
<td>Top 10</td>
<td>64.86</td>
<td>32.85</td>
</tr>
<tr>
<td>Top 100</td>
<td>82.99</td>
<td>51.27</td>
</tr>
<tr>
<td>Top 1,000</td>
<td>93.34</td>
<td>71.79</td>
</tr>
<tr>
<td>Top 10,000</td>
<td>98.73</td>
<td>92.05</td>
</tr>
</tbody>
</table>

We consider first the results with \(\sigma = 2.98\), taken from EKK (2011). In that case, we do not come close to capturing the substantial contribution (shown in Table 2) of the largest French exporters. Conversely, increasing \(\sigma\) to 7.09 goes too far, with the top 100 firms accounting for more than 80 percent of French exports. The simulations with \(\sigma = 5.64\) (and hence \(\theta/(\sigma - 1) = 1.05\)) match most closely the data in Table 2. The last three columns of Table 6 show that there is substantial variation in the contribution of the largest French exporters across simulation runs; however, in all cases, the middle value of \(\sigma\) delivers results that are closest to the data.\(^{34}\)

### 5.5 Entry Costs

From the results of the previous section, we can calculate the gross profits of the \(k\)th lowest cost firm in market \(n\) as:

\[
\Pi_n^{\hat{R}_n}(C_n^{(k)}) = \left[1 - \frac{C_n^{(k)}}{p_n^{\hat{R}_n}(C_n^{(k)})}\right] \left(\frac{p_n^{\hat{R}_n}(C_n^{(k)})}{P_n^{\hat{R}_n}}\right)^{-(\sigma-1)} X_n
\]

We calculate upper and lower bounds \(E_n\) and \(\bar{E}_n\) on the entry costs as:

\[
E_n = \Pi_n^{\hat{R}_n}(C_n^{(R_n)})
\]

\[
\bar{E}_n = \Pi_n^{\hat{R}_{n+1}}(C_n^{(R_n+1)})
\]

\(^{34}\)Our grid of parameter values is coarse. We leave it to future work to carry out a more formal estimation procedure.
In the simulations that follow, we set $\hat{E}_n = E_n$, although bounds are so tight that in the following figures the upper and lower would appear the same. The implied entry costs range from $1000$ to $32,700$.

We plot these values against mean sales across countries in Figures 5a. The relationship is tight, with an elasticity close to 1. In the continuum model, the elasticity would be exactly one. Figure 5b plots the entry costs against total absorption of manufactures. The relationship is noisier, with an elasticity of 0.29.\footnote{Even though Cournot competition implied much larger markups for the biggest firms, the entry costs were very similar to the Bertrand case.}

We are now fully equipped to look at the implications of various changes in the environment. In particular, knowing the entry costs, we can examine how such changes would affect the number of firms active in different markets.

6 Two Experiments

With values for $E_n$, we can combine our simulation of unit costs and simulation of sales from the previous section (which were conditional on the number of entrants $K_n$) to simulate a new global equilibrium in which entry into each market is endogenous. We continue to use the $\hat{\pi}_{ni}$ (from our estimation of the gravity equation), $\theta = 4.87$, and $\sigma = 5.64$.

We do simulations of two types. One type examines the effect of changes in exogenous parameters, such as those governing trade costs $d_{ni}$ and competitiveness $S_i$. We do these simulations using the same normalized cost draws $U^{(k)}$ as in the previous analysis. We hold the $U^{(k)}_i$'s fixed in conducting these counterfactuals in order to isolate the role of the parameters
under consideration from changes introduced by a resampling of technology.

The second type focuses on the sensitivity of aggregate outcomes to the technology draws of the individual firms. A major part of our analysis seeks to understand the sensitivity of the aggregate equilibrium to these draws. To assess their importance, we examine the implications of drawing different sets of $U_i^{(k)}$’s given the parameters of the model.

In either type of simulation, the number of firms $K'_n$ entering a given market $n$ is determined by the condition:

$$\Pi_n^{K'_n+1}(C_n^{(K'_n+1)}) < \hat{E}_n \leq \Pi_n^{K'_n}(C_n^{(K'_n)}).$$

Figure 5a. Comparison of estimated $\hat{E}$ and mean sales

Regression: $\ln \hat{E}_n = -4.1197 + 0.9377 \times \ln X_n$

36 In attempting to simulate the continuum model with a (computationally necessary) finite set of draws, sampling error would be a nuisance that researchers would want to minimize by sampling to the extent allowed by their hardware and patience. In our finite-firm model, sampling “error” is an integral part of the economic environment. Specifically, aggregate outcomes do indeed depend on the individual firms’ luck of the draw.
6.1 Globalization

We begin by considering the consequence of a 10 percent decline in trade costs between countries. This experiment is similar to that carried out in EKK (2011) using a continuum model. In that experiment, some individual firms entered export markets and others were driven out of their home market. In our experiment here, with a finite-firm model, entire countries may enter new export markets. This counterfactual experiment illustrates the first type of simulation described previously, in which technology draws are held fixed as we consider the equilibrium implications of a change in the model parameters.

For each country pair $n \neq i$, we set the counterfactual trade cost to $d'_{ni} = d_{ni}/1.1$.\footnote{This change is equivalent to adding a constant $\theta \ln(1.1) = 0.464$ to each of the parameters $m_n$ that appear}
The decline in trade costs will alter the simulations by providing counterfactual values $\hat{\pi}_{ni}'$ to replace $\hat{\pi}_{ni}$ for constructing unit costs (for given $U_i^{(k)}$’s). These counterfactual values relate to the baseline values $\hat{\pi}_{ni}$ according to:

$$\hat{\pi}_{ni}' = \frac{\hat{\pi}_{ni}(1.1)^\theta}{\hat{\pi}_{nn} + \sum_{l \neq n} \hat{\pi}_{nl}(1.1)^\theta}.$$

After computing equilibrium entry $K_n'$ together with a Bertrand equilibrium in prices, we can evaluate the resulting counterfactual trade flows $X_{ni}'$.

World exports rise by 43 percent due to lower trade costs, in line with results in EKK (2011). Although nearly all of this increased trade occurs within pairs of countries that were already trading, 99.9984 percent, there are still perceptible changes along the extensive margin. Overall, 206 new trade flows emerge between country pairs for which one had not previously exported to the other. Among countries in the lowest-size quartile (measured by absorption of manufactures), the average number of export destinations increases by nearly 12 percent; however, sales in these new markets account for less than 0.2 percent of the increase in the value of their exports.

### 6.2 Granularity

Our second simulation evaluates the importance for aggregate outcomes of the luck of the technology draw at the level of individual firms. We look at variation in the manufacturing price level at the country level and at the role of the largest global firms. This experiment illustrates the second type of simulation in which parameters are held constant but technologies of all potentially active firms are redrawn repeatedly, with aggregate equilibrium outcomes in the gravity equation estimated in Section 5.1.
recalculated for each draw.

For each draw of technologies, generating a new set of costs $C_n^{(k)}$ in each market $n$, we calculate the equilibrium number of entrants $K'_n$ and Bertrand equilibrium prices $p^{K'_n}(C_n^{(k)})$ to evaluate the log of the manufacturing price level:

$$\ln P'_n = \frac{-1}{\sigma - 1} \ln \left( \sum_{k=1}^{K'_n} \left[ p^{K'_n}(C_n^{(k)}) \right]^{-(\sigma-1)} \right).$$

We present the $\ln P'_n$ for each simulation relative to its mean across all 200 simulations.

Figure 6 shows the results for two values of $n$, the United States and Denmark. Each point on the scatter represents the percentage deviation (calculated as the log difference) of the price level for the United States and Denmark for one of the 200 simulations. The variance for Denmark is 24.4 compared to 14.4 for the United States. Although it is notably smaller for the larger country, it remains substantial even in the largest destination. By plotting the results for both countries in the same figure, we capture the extent to which the model generates outcomes that move together across countries due to international trade. The results point to positive covariation, with a correlation of 0.48.

In some cases, the same firm is the top firm in both the United States and Denmark, in which case Figure 6 indicates its origin with a three-letter abbreviation. For example, along the northwest frontier of the scatterplot, the top firm in both the United States and Denmark often is a U.S. firm. It is not surprising that in these cases the United States has a low price level, whereas Denmark’s is not so low. On the east-by-southeast frontier of the scatterplot, the largest firm in each country is often European, leading to a lower price level in Denmark than in the United States. In one case, the top firm is from Guatemala and in another case
Vietnam, demonstrating the possibility of extreme outcomes in this model. For the vast majority of the observations, the top firm in Denmark is different than the top firm in the United States. For the United States, a U.S. firm is at the top in 180 simulations, whereas Denmark’s top firm is Danish in 105 simulations.

7 Conclusion

In this chapter, we amend a standard heterogeneous-firm model of exporting by keeping the number of firms finite. Our quantification of the model suggests that it can fit well a number of features of the data.
Finiteness introduces both richness and complexity. To focus on its specific contribution, we keep our model simple in other dimensions. First, we introduce only one dimension of firm heterogeneity, underlying efficiency. Second, we do not incorporate endogenous entry costs, as in Arkolakis (2010).

As a consequence, the model makes some obviously false predictions. By stripping out additional dimensions of heterogeneity, firms from the same source will enter markets according to a strict hierarchy (i.e. a firm will always sell in an easy-to-enter market if it sells in a more-difficult market), and multiple firms from the same source selling in common destinations will always rank the same in terms of relative sales in each destination. By ignoring the endogeneity of entry costs, the model cannot account for systematic deviations from Zipf’s law among small exporters.

EKK (2011) show how introducing heterogeneity to a firm’s cost of entry and to its demand in each market, as well as adopting Arkolakis’s formulation of endogenous entry costs, can break these rigid predictions. With these embellishments, the standard Melitz model can replicate multiple features of the data (although, of course, it fails to explain how zeros can arise in the trade data). Introducing additional sources of firm heterogeneity and endogenous entry costs into the model developed here should serve the same purpose in loosening this rigidity. In addition, we conjecture that introducing these features would improve the model’s ability to predict zeros among very small source countries. These additions pose modeling challenges that we hope future research will overcome.

The domain of macroeconomics has been the study of aggregate relationships, whereas industrial organization focuses on the interaction of individual firms. Our exploratory analysis
in this chapter, in building a bridge (or perhaps only a tightrope) connecting their two domains, provides a new perspective on empirical relationships in international trade.

References


“Firms in International Trade,” Journal of Economic Perspectives, 21: 105-130.


