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THE MARGINS OF TRADE

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Welfare depends on the quantity, quality, and range of goods consumed. We use trade data, which report the quantities and prices of the individual goods that countries exchange, to learn about how the gains from trade and growth break down into these different margins. Our general equilibrium model, in which both quality and quantity contribute to consumption and to production, captures (i) how prices increase with importer and exporter per capita income, (ii) how the range of goods traded rises with importer and exporter size, and (iii) how products traveling longer distances have higher prices. Our framework can deliver a standard gravity formulation for total trade flows and for the gains from trade. We find that growth in the extensive margin contributes to about half of overall gains. Quality plays a larger role in the welfare gains from international trade than from economic growth due to selection.

KEYWORDS: international trade, variety, prices, quality, heterogeneous firms.

1. INTRODUCTION

Quantitative work in international trade has advanced on several fronts in the last two decades. One line of research has developed global general equilibrium models to understand bilateral trade flows and their implications for welfare.[1] Another literature has delved into trade data to ask how total bilateral exports decompose into the number of products (the extensive margin) and sales per product (the intensive margin), and how sales per product decompose into quantity and unit value.[2] These studies have revealed several robust and intriguing regularities.

Both lines of research have been extremely fruitful, but remain somewhat at odds with each other. Capturing a complex world with a general equilibrium system has required assumptions inconsistent with richer countries paying more for the same product and richer countries charging more for the same product, two of the most robust regularities to emerge from this second line of inquiry. Incorporating how trade volumes break down into their extensive and intensive margins has also proved challenging for general equilibrium modeling. But without these breakdowns we have no way of predicting the extent to which gains from trade or growth take the form of increased quantity, increased quality, or a greater range of goods.

This paper integrates these two research fronts with a general equilibrium framework consistent with observed regularities in the margins of trade. In our specification here aggregate values

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Fieler: Yale University and NBER (ana.fieler@yale.edu). Jonathan Eaton passed away in February 2024. It was a privilege to be his mentee, co-author, and friend. He was greatly missed during the revision and will continue to be missed in so many other ways. We thank Sam Kortum, Eduardo Morales, and David Weinstein for valuable suggestions. Jonathan Eaton received support from the National Science Foundation under Grant Number 1426267.

[1]Early examples are Anderson and Van Wincoop (2003), using an Armington approach, Eaton and Kortum (2002), whose approach is Ricardian, and quantitative papers building on Melitz (2003), such as Chaney (2008) and Eaton et al. (2011).

[2]Early contributions here are Schott (2004), Hummels and Klenow (2005), and Hallak (2006).

of bilateral trade adhere to a standard gravity formulation consistent with the assumptions in Arkolakis et al. (2012).[3] Hence standard measures of the gains from trade apply.

In line with much previous work, we associate differences in unit value with differences in quality.[4] Our modeling of quality integrates two approaches that previous research has pursued individually.

One type of quality substitutes perfectly for quantity. All users of a variety, whether a household using the variety for final consumption or a producer using the variety as an intermediate input, value this quality equally. Models of trade with this type of quality, which we call substitutable quality, include Khandelwal (2010), Hallak and Schott (2011), Kugler and Verhoogen (2011), Johnson (2012), Khandelwal et al. (2013), Crozet et al. (2012), Chen and Juvenal (2016), and Lashkaripour (2020b). Quantitative work has focused on the prices of suppliers, e.g., exporting countries or individual firms.

The other type of quality complements quantity. A buyer using more of the variety values this quality more than a buyer using less. Hence a buyer making a larger purchase of a variety devotes increased spending to more quality as well as to more quantity. Flam and Helpman (1987) provide an early model of trade with this type of quality, which we call complementary quality. Subsequent contributions include Stokey (1991), Choi et al. (2009), Fajgelbaum et al. (2011), Bekkers et al. (2012), Feenstra and Romalis (2014), and Handbury (2021). Quantitative work has focused on the prices of buyers, e.g., importing countries or households.

Our general equilibrium framework is one of monopolistic competition, building on Melitz (2003), Chaney (2008), and Eaton et al. (2011).[5] We posit that substitutable quality increases with the efficiency of the firm producing it and with the firm's employment of intermediates per worker. An implication is that more efficient firms, penetrating more distant markets, sell at a higher price, generating a correlation between unit value and distance. Another implication is that firms from high wage countries employ more intermediates per worker (in terms of both quantity and quality), so sell everywhere at a correspondingly higher price. In equilibrium, a firm provides the same substitutable quality wherever it sells. But, to accommodate differences among buyers, the same producer may sell different complementary qualities to different destinations. We can thus capture why unit values increase in both exporter and importer per capita incomes while delivering a homothetic gravity equation in which the volume of trade doesn't increase with income similarity.[6]

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[3]To obtain the standard gravity formulation, we embed our specification of technology and aggregation as it applies to individual varieties, which delivers these margins, into a standard homothetic CES aggregator. We could instead have embedded them into a more general framework with nonhomothetic aggregation or differences in trade elasticities across classes of varieties, as in Fieler (2011), Adão et al. (2017)), or Comin et al. (2021), among others.

[4]Aside from Schott (2004), Hummels and Klenow (2005), and Hallak (2006), other authors making this connection are Hummels and Skiba (2004), Feenstra and Romalis (2014), Baldwin and Harrigan (2011), and Atrianfar (2019). Taking an alternative approach, Lashkaripour (2020b) interprets patterns of unit values in trade data as reflecting heterogeneous markups, extending Krugman (1979) to allow for different classes of goods with different elasticities of substitution. His approach doesn't deliver the standard homothetic gravity equation for aggregate trade consistent with our approach here.

[5]A previous version of this paper develops these ideas in a perfectly competitive Ricardian framework, in line with Eaton and Kortum (2002). Feenstra and Romalis (2014), who explain how prices rise with distance and importer per capita income, also build on Melitz (2003), but introduce a specific trade cost inconsistent with the gravity equation. Using data on U.S. exports, Baldwin and Harrigan (2011) find that the United States exports more products at lower prices to larger and closer destinations, demonstrating how these facts can emerge from a model of firm heterogeneity with substitutable quality differentiation. Crozet et al. (2012) use a model with firm heterogeneity and substitutable product differentiation to understand why higher-quality French champagne producers export more widely.

[6]A model with substitutable quality alone, such as Khandelwal (2010), can explain why rich countries export at higher unit values but not why rich countries import at higher unit values. A model with complementary quality alone, such as Flam and Helpman (1987), with rich countries having a comparative advantage in high complementary

Our monopolistic competition approach also allows us capture the extensive margins of trade: Larger countries both export and import a wider range of products.[7] A larger country has both more exporting firms and serves as a destination for more exporting firms from elsewhere. To explain why a country often imports the same product from multiple sources, we treat products in the data as random clusters of varieties in the model. As countries grow they fill in the space of products, generating the nonlinear relationship between size and the extensive margins apparent in the data.[8]

Our main source of data is Comtrade, which reports annual bilateral trade between most countries, in terms of both value and physical quantity, using an extensive harmonized product classification. It thus provides unique insight into what countries across all sizes and income levels produce (as exporters) and absorb (as importers). We estimate the parameters of the model using these data as well as data on country characteristics. The model can replicate the empirical regularities on quantity, price, and range of goods in bilateral trade identified by Schott (2004), Hummels and Klenow (2005), Hallak (2006), and Baldwin and Harrigan (2011), among others.

Our framework shows the extent to which welfare gains take the form of larger quantity, higher quality, or a broader range of goods consumed. We find that about half of consumers' benefit from a foreign shock comes from an increased range of varieties, the extensive margin, but that aggregation into coarse product categories masks the contribution of this margin. Quality plays a larger role in the welfare gains from trade than from economic growth because of the selection of more productive, higher-quality firms into international trade.

We proceed as follows: Section 2 documents the striking regularities in the bilateral trade data that our analysis builds on. Section 3 presents our general equilibrium model of quality differentiation and trade. We present our estimation of the model in Section 4. Section 5 addresses what our analysis implies for the gains from trade and growth, and how these gains are manifest in the range of products available, their quality, and quantity. Section 6 concludes.

2. REGULARITIES IN THE TRADE DATA

We review first-order regularities that emerge from the data, many of which have been documented before. These regularities motivate our key departures from standard gravity modeling in Section 3 that follows.

Our trade data are from the United Nations Statistics Division (n.d.), Comtrade, the primary depository of data on international trade. Participating countries report their annual merchandise trade broken down by partner country and by commodity according to a uniform classification.

We present results for 2007, working with the most disaggregated product category, which is HS6.[9] We refer to an HS6 product category as a product. We restrict our analysis to trade

quality, can explain both margins, but delivers the counterfactual implication that bilateral trade diminishes with differences in per capita incomes. See Section 2.2.

[7]The large literature on the extensive margin of trade goes back at least to Vernon (1966)'s product cycle model. More recent contributions include Evenett and Venables (2002), Besedeš and Prusa (2006) (for U.S. imports), Besedeš and Prusa (2011), Regolo (2013) and Baier et al. (2014) (for exports), Amiti and Freund (2010) (for Chinese exports), Debaere and Mostashari (2010) (for both margins), Cadot et al. (2011) and Kehoe and Ruhl (2013) (looking at the role of the extensive margin in growth), and Silva et al. (2014) (who consider the role of the extensive margin for gravity estimation).

[8]This assignment of firm-level varieties in the model to product categories generates randomness in the products traded through granularity, as in Eaton et al. (2013) and Armenter and Koren (2014).

[9]As shown in Appendix A.6 in Fieler and Eaton (2024), data for 2001, 2002, 2012, and 2017 reveal similar results.

TABLE I

DECOMPOSITION OF TRADE FLOWS

dependent variable →	value	extensive margin	quantity	price
Panel A				
exporter GDP	1.35	0.88	0.45	0.02
importer GDP	1.10	0.40	0.66	0.04
distance	-1.18	-0.72	-0.52	0.06
Panel B				
exporter GDP per capita	1.34	0.92	0.32	0.10
exporter population	1.35	0.85	0.55	-0.05
importer GDP per capita	1.08	0.45	0.51	0.12
importer population	1.12	0.35	0.79	-0.02
distance	-1.19	-0.68	-0.63	0.12
number of observations	9,455	9,455	9,455	9,455

Note: All variables are in logs. We report standard errors in Table A.IV.

among the 100 largest countries in terms of 2007 GDP.[10] Our analysis augments Comtrade with data on GDP and population from the The World Bank Group (n.d.), the World Development Indicators, and with data on geographical characteristics from the Centre d'Études Prospectives et d'Informations Internationales (2011), CEPII, described by Mayer and Zignago (2011). Appendix A.1 provides a list of the countries and further detail on the construction of our data.[11]

2.1. *Gravity and Its Margins*

A long-recognized feature of bilateral trade data is gravity: The value of bilateral trade between two countries is approximately proportional to each trading partner's GDP and to the inverse of the distance between them. The first column of Panel A of Table I, reporting a regression of the value X_{ni} (in logs) of exports to destination n from source i, confirms that our data respect this relationship (with the three elasticities a little in excess of one). The same column of Panel B shows that breaking importer and exporter GDP into GDP per capita and population doesn't matter.

But underneath this simple relationship are a number of more subtle, but similarly robust, regularities. In our first exercise, we follow Hummels and Klenow (2005) in decomposing

[10]We remove small countries to avoid zero bilateral trade flows and to ensure sufficient overlap in HS6 products across importer-exporter pairs. Among the 100 countries in our sample, Comtrade reports total merchandise trade of US $12.9 trillion representing 98 percent of the value of trade in the sample of countries with GDP data. For the reasons described in Appendix A.1, we pare the data on unit values down to 4,520,028 importer-exporter-product triads, 87 percent of the triads with unit value data for the 100 selected countries.

[11]We use data reported by the importing country whenever available. Appendix B.1 compares the empirical regularities in the data reported by the importer to those reported by the exporter.

Centre d'Études Prospectives et d'Informations Internationales (2010) provides a user friendly version of the Comtrade data, BACI, described by Gaulier and Zignago (2010). Among other things, BACI reconciles potentially conflicting reports on unit values from importing and exporting countries. Concern that CEPII's procedures for refining the data might influence some of the regularities we explore here led us to use the raw data downloaded directly from the Comtrade website. But as Appendix B.2 shows, the empirical regularities on unit values here hold also in BACI.

X_{ni} into an extensive margin E_{ni}, a quantity margin, and a price margin P_{ni}. We define the extensive margin E_{ni} as the fraction of HS6 products that n imports from i. We create the price margin from data on the unit value p_{nik} of each product k imported by each destination n from each source i.[12] Specifically, $\log P_{ni}$ is the fixed effect for importer-exporter dyad ni in the regression:

$$\log p_{nik} = \log P_{ni} + \delta_k + \varepsilon_{nik}, \tag{1}$$

where δ_k is a fixed effect for product k. We define the quantity margin as the residual $X_{ni}/(E_{ni}P_{ni})$.[13]

How does gravity account for these three margins of bilateral trade individually? Table I reports the results. The coefficients in the last three columns sum to the corresponding coefficient in the first.

How GDP relates to the extensive margin differs between importer and exporter. Larger countries export many more products than smaller countries, but they don't import so many more. As shown in Panel B, separating GDP into population and GDP per capita again doesn't matter much for the extensive margin.

The last two columns decompose the intensive margin into quantity and price. Looking only at total GDP (Panel A) the action is almost all in the quantity margin. But breaking GDP into GDP per capita and population in Panel B shows that prices tend to rise with both exporter and importer GDP per capita (with elasticities 0.10 and 0.12, respectively) and to fall slightly with population (insignificant for the importer). Also note the positive effect of distance on price, with an elasticity of 0.12, the Alchian-Allen effect analysed by Hummels and Skiba (2004).

We calculate the contributions of exporter fixed effects, importer fixed effects, and distance to the overall variance of $\log P_{ni}$, weighting the $\log P_{ni}$ of each importer-exporter dyad by the number of product categories traded by the pair with quantity and value data. The contributions are 0.53, 0.33, and 0.21 respectively. Hence each single source of variation makes a substantial contribution to variation overall.

2.2. *Price Relationships*

A drawback of the price data in the regressions of Table I is that, for many importer-exporter dyads, there are only a few price observations. This paucity of data can give rise to measurement error in P_{ni}. To exploit the full range of variation in prices, giving greater weight to products and to dyads with more trade, Table II reports regressions of unit values for each importer-exporter-product triad p_{nik} against importer and exporter characteristics.

[12]We construct p_{nik} from Comtrade by dividing, for each importer-exporter-HS6 triad, the reported value by the reported quantity. Values are always in terms of current U.S. dollars. Of the importer-exporter-product triads with quantity data, 80 percent report quantities in terms of weight (corresponding to 73 percent of the total value of trade in our analysis). The remaining triads are nearly all in terms of counts. See Appendix A.1 for details. Appendix Table A.XI reports the descriptive price regression in Table II column (3) using only data on counts. Lashkaripour (2020a) provides an analysis of alternative quantity measures in trade data.

[13]These definitions differ from Hummels and Klenow (2005), who use a weighted definition of the extensive margin and construct the price margin using the price index introduced by Sato (1976) and Vartia (1976) and discussed extensively by Feenstra (1994). Table A.XII shows that qualitatively our results hold using their definition. In our data, the correlation between our measures and theirs is 0.91 for the extensive margin and 0.63 for prices. Our simpler definitions are more tightly linked to the product-level analysis below and to our model.

Hummels and Klenow (2005) find that the increasing relation between prices and exporter per capita income holds only among the richest exporters in their data. We find no evidence of this distinction in our data. See Tables A.IX and A.X .

TABLE II

DESCRIPTIVE PRICE REGRESSIONS

	Price for each importer, exporter, product p_{nik}				Weighted reg., P_{ni} [b]
	(1)	(2)	(3)	(4)	(5)
exporter GDP per capita	0.162		0.168	0.170	0.162
	(0.019)		(0.018)	(0.018)	(0.018)
exporter population	-0.069		-0.064	-0.064	-0.063
	(0.022)		(0.021)	(0.021)	(0.021)
importer GDP per capita		0.094	0.102	0.110	0.100
		(0.016)	(0.015)	(0.014)	(0.015)
importer population		-0.028	-0.018	-0.019	-0.018
		(0.013)	(0.013)	(0.013)	(0.013)
distance	0.148	0.147	0.119	0.114	0.116
	(0.020)	(0.014)	(0.017)	(0.019)	(0.017)
absolute difference in GDP per capita[a]				0.023	
				(0.014)	
product-importer fixed effect	yes	no	no	no	-
product-exporter fixed effect	no	yes	no	no	-
product fixed effect	no	no	yes	yes	-
Number of observations	4,520,030	4,520,030	4,520,030	4,520,030	9,455
R-squared	0.818	0.808	0.768	0.768	0.487

Note: Notes: All variables are in logs. Standard errors in parentheses are clustered by importer and by exporter. [a]The term equals |log(importer GDP per capita/exporter GDP per capita)|. [b] Each observation P_{ni} is weighted by the number of product-level price observations p_{nik} for the importer-exporter dyad ni.

Column (1) reports a regression of unit values p_{nik} against distance, exporter GDP per capita, exporter population, and importer-product fixed effects. The coefficient on exporter per capita income is 0.16, much larger than in Table I. It implies that individual importers buy the same product from richer countries at systematically higher prices.[14] The coefficient on exporter population -0.07 implies that exporters from larger countries sell at lower prices.

Column (2) reports the mirror regression of unit values against distance, importer GDP per capita, importer population, and exporter-product fixed effects. The coefficient on importer per capita GDP is 0.094, not far from Table I. Exporters systematically charge richer countries higher prices for the same products.

Column (3) reports what happens if we use only product fixed effects with both exporter and importer per capita income and population as well as distance. The coefficients on these variables don't change much from columns (1) and (2). Similar to Table I, the elasticity of prices with respect to distance is 0.12, and importer population isn't significant.

Column (4) includes the absolute value of the difference between exporter and importer GDP per capita (in logs). The coefficient is small and statistically insignificant. Hence we find no evidence that rich countries disproportionately pay more for goods from other rich countries.

In column (5), the dependent variable is the price index P_{ni} as in the price regressions of Table I. Here, we weigh the observation of each importer-exporter dyad ni by the number of products with price data p_{nik}, to account for larger measurement error in dyads with few price

[14]Schott (2004) reports similar results for imports into the United States at the level of 10-digit product categories.

TABLE III

DESCRIPTIVE PRICE REGRESSIONS BY SELECTED PRODUCT CATEGORIES

	Price for each importer, exporter, product p_{nik}.				
	all products		Rauch (1999)	BEC end-use classification	
	Table II col (3)	manufact.	differentiated	consumption	capital, inputs
	(1)	(2)	(3)	(4)	(5)
exporter GDP per capita	0.168	0.176	0.170	0.166	0.172
	(0.018)	(0.019)	(0.018)	(0.017)	(0.023)
exporter population	-0.064	-0.076	-0.077	-0.066	-0.066
	(0.021)	(0.024)	(0.023)	(0.020)	(0.022)
importer GDP per capita	0.102	0.106	0.113	0.154	0.079
	(0.015)	(0.016)	(0.016)	(0.016)	(0.016)
importer population	-0.018	-0.006	-0.007	0.001	-0.028
	(0.013)	(0.014)	(0.014)	(0.016)	(0.013)
distance	0.119	0.107	0.112	0.090	0.132
	(0.017)	(0.020)	(0.019)	(0.016)	(0.019)
product fixed effect	yes	yes	yes	yes	yes
Number of observations	4,520,030	2,940,221	3,156,443	1,028,272	2,643,031
R-squared	0.768	0.772	0.767	0.668	0.782

Note: Notes: All variables are in logs. The dependent variable is the price by importer-exporter-product triad p_{nik}. Standard errors are clustered by importer and by exporter. We use Rauch's liberal classification which has fewer differentiated goods. BEC refers to the United Nations classification of goods according to end use. We use HS2 codes 50-96 as manufactures, which excludes the initial processing of raw materials. See Table A.VII for industry codes. Tables A.V and A.VI report the results for non-manufactures, and other categories in BEC and Rauch (1999).

observations. Reassuringly, the coefficients in this corrected regression are close to those of column (3).[15]

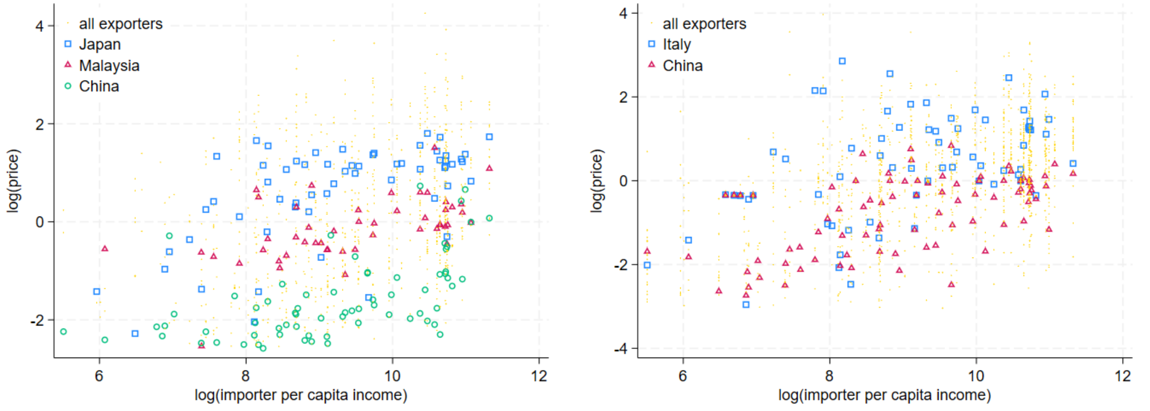
Table III considers the sensitivity of the results to the set of products.[16] We restrict the sample to manufactures in column (2) and to products classified by Rauch (1999) as differentiated in column (3). In neither case are the results notably different from the full sample in column (1) (copied from Table II, column (3)).

The next two columns use the United Nations' classification according to the end usage, Broad Economic Categories (BEC).[17] We restrict the sample to final consumption goods in column (4) and to intermediate inputs and capital goods in column (5). In both cases, the coefficients on distance, on importer and on exporter per capita income remain positive and statistically significant, while the coefficient on exporter population remains negative and sta-

[15]An additional potential issue with the price regression in Table I is selection bias. Say that the price of a product didn't vary on average by importer or by exporter. A positive importer or exporter elasticity could still emerge if rich countries didn't sell their cheaper products to poor countries or if poor countries didn't sell their more expensive products to rich countries. Since selection would bias column (5) and not column (3) of Table II, the similarity between these two columns show that forces other than selection are at work.

[16]The estimation below focuses on the elasticities of price with respect to country characteristics at the HS6 product level, ignoring broader product classifications. Appendix A.4 examines the regularities in prices separately by industry classification, at the section and HS4 classifications. We find that these broader tiers left so much within-industry heterogeneity on the table that there was little to be gained by grouping HS6 products into broader categories when estimating the model. Appendix A.3 reports the results for non-manufactures, and other categories in BEC and Rauch (1999).

[17]See United Nations Statistics Division (2016a,b) for the manual and download information.



(a) Bicycle pedals and crank gear (HS871496)

(b) Baby garments (HS620990)

FIGURE 1.—Price-income relationships for two products

tistically significant. In our theory, nonhomothetic demand comes both from households and from firms buying intermediate inputs. Thus, it explains the increasing relation between prices and importer per capita income of final goods and intermediate inputs.

Income elasticities of prices. The coefficients on exporter and importer per capita income in Table II imply substantial variation in prices across both exporters and importers for a particular product, to the extent that a rich exporter sells to a poor importer at a price below that at which a poor exporter sells to a rich importer. A back-of-the-envelope calculation based on the regression coefficients in column (3) of Table II implies, for example, that a Malaysian product should sell in Norway at 50 percent more than a Japanese product in Ethiopia.

To illustrate these pricing patterns for individual products, Figure 1 shows prices for HS6 categories HS871496, bicycle pedals and crank gear, and HS620990, baby garments.[18] The figures plot unit values against importer per capita income for all importer-exporter pairs. For pedals and crank gear, we highlight three major Asian exporters: China (GDP per capita US$2,721) with a circle, Malaysia (GDP per capita US$11,358) with a triangle, and Japan (GDP per capita US$34,313) with a square. Across destinations, Japan's unit values are higher than Malaysia's, which are higher than China's. For all three exporters, unit values rise with the importer's GDP per capita, so much so that Japan is selling in the poorest destination at a price lower than the price at which China sells in the richest destination.

For baby clothes, Figure 1(b) highlights two of the largest exporters, China with triangles and Italy with squares (GDP per capita US$35,396). Note how China sells to the richest country, Norway (GDP per capita US$82,480), at a price above that at which Italy sells to its poorest buyer, Ethiopia (GDP per capita US$247).

Going back to Flam and Helpman (1987), the literature on quality and trade has provided an explanation for why unit values rise with both exporter and importer per capita income: Rich countries have a comparative advantage in producing high quality, and hence charge higher prices, and because of nonhomotheticity in preferences, rich countries have a greater taste for

[18]See hts.usitc.gov for more complete product definitions.

quality, so pay higher prices.[19] The regularities reported here pose at least two challenges for these models.

First, the assumption that rich countries have a comparative advantage in high quality implies that, as long as quality is one dimensional, there should be no overlap in the prices charged for a given product by a rich country and a poor country. With only one dimension of quality, the overlap implies that Malaysia is selling a higher quality to rich countries than Japan is selling to poor countries. Otherwise, rich countries would prefer the Japanese, cheaper variety. But Japan has revealed that, within any destination, it's quality is higher.[20]

As long as quality has only one dimension, horizontal product differentiation doesn't explain these price overlaps either. In Figure 1(a), consider the exports from Japan and Malaysia around the x-axis, with log(price) ≈ 0. If these goods were horizontally differentiated and had similar qualities, then we should observe them in all destinations, not systematically only the Malaysian goods in rich countries and only the Japanese goods in poor countries.

Second, these models imply that rich countries, with a comparative advantage in high-quality goods, should sell primarily to rich households in poor countries, since high quality goods are income elastic. Similarly, poor countries should sell primarily to poor households in rich countries. Since rich countries have more rich households and poor countries have more poor households, trade between countries should systematically decline with differences in income per capita. Our data provide little evidence that it does.[21]

2.3. *The Extensive Margins*

To probe further into the extensive margin of trade, Figure 2 plots the fraction of HS6 product categories that a country exports (a) and the fraction that it imports (b) against its total GDP (all in logs). Consistent with the results in Column 2 of Table I, the extensive margin varies much more for exporters than for importers (hence the very different scales for the two y-axes). Not revealed by the regression is the concave relation between these extensive margins and GDP: For the largest countries, the relationship between GDP and extensive margin levels off, both for imports and for exports.

Exporters and Importers per Product. Analysis of the extensive margin has typically addressed the number of products a country exports or imports. A different cut is the number of countries exporting or importing a given product. Among our 100 countries, an HS6 product

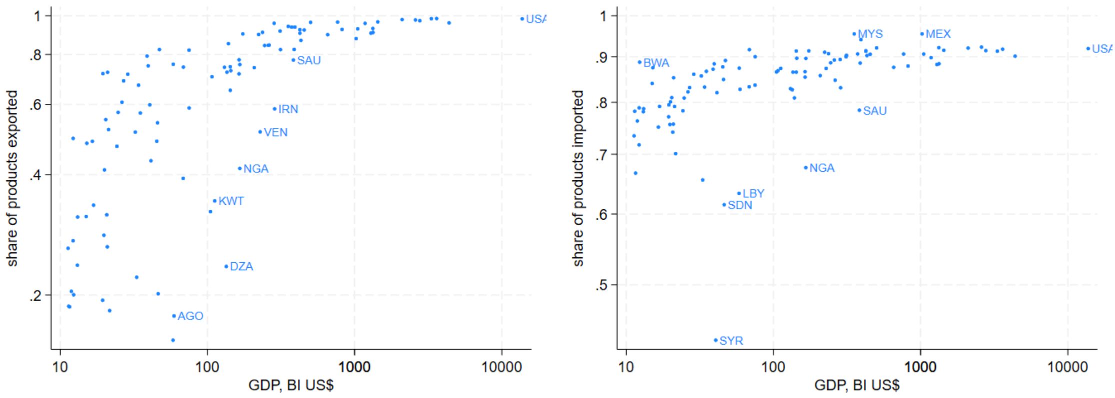
[19] Subsequent papers in this tradition include Stokey (1991) and Fajgelbaum et al. (2011).

[20] Appendix C.1 formalizes this argument in a toy model with perfect competition. Variable markups provide an alternative explanation for why prices increase with importer per capita income if rich households have a low price elasticity of demand as in Simonovska (2015). Markups do not explain why richer countries export goods at higher prices or why they pay more for their intermediate inputs.

Ottaviano et al. (2002) use markups to explain patterns of firm behavior that we do not observe here. For example, firms charge lower markups in competitive, urban destinations and incompletely pass through their trade costs.

[21] We introduced various measures of the difference in trade partners' per capita incomes into a standard gravity equation. They had either no effect on trade or increased it slightly. For example, we included the absolute value of the log of the ratio of the partners' incomes per capita in a regression of bilateral trade volumes (in logs) on exporter and importer fixed effects and log distance. The coefficient was 0.060 (s.e. 0.020) with OLS and 0.021 (s.e. 0.025) in a Poisson regression. The absence of an effect is consistent with earlier findings. See for example Hallak (2010).

A back-of-the-envelope calculation suggests that departures from gravity would be large in a model with one dimension of quality. Based on the coefficients of column (3) of Table II, we expect the Japanese prices to be about 29 percent higher than the Chinese prices for imports and 53 percent higher for exports. This larger variation in the price of exports, implies that if the Chinese exports were well suited for Chinese households, then the Japanese exports would be well suited for consumers with income even higher than a typical Japanese household. There are very few of these households in poor countries.



(a) Exporter

(b) Importer

FIGURE 2.—Extensive margin and GDP (different y-axis scales)

has an average of 65 exporters, with 35 at the 10th percentile and 91 at the 90th.[22] Our strategy for bundling varieties into products, described in Section 3.5, captures both versions of the extensive margins we report here.

3. THE MODEL

Our model of trade accommodates these nuanced features of the data while respecting the basic homothetic gravity relationships that hold robustly between aggregates. It explains why prices rise as they do with both importer and exporter per capita income and with distance, while accounting for the extensive margins of trade in the importer, exporter, and product dimensions.

3.1. *Varieties and Aggregation*

We begin with how our two dimensions of quality interact with physical quantity in demand and supply, embedding these features into multi-country general equilibrium below.

Demand. There are a continuum of varieties, indexed by $\omega \in \Omega$, both enjoyed by consumers in consumption and used by firms in production. For either purpose varieties aggregate according to:

$$Y = \left[\int_{\omega \in \Omega} u(\omega)^{\beta} d\omega \right]^{1/\beta} \tag{2}$$

where the variety-specific benefit is:

$$u(\omega) = \left[(Q(\omega) y(\omega))^{\rho} + q(\omega)^{\rho} \right]^{1/\rho}. \tag{3}$$

[22] Importing is less concentrated than exporting. Among our 100 countries an HS6 product has on average 84 importers, with the 10th percentile having 46 and the 90th all 100. Across HS6 products, the correlation between the number of importers and number of exporters is 0.80.

Here $y(\omega)$ represents the physical amount of variety ω, $Q(\omega)$ its substitutable quality, and $q(\omega)$ its complementary quality. Note how quality $Q(\omega)$ perfectly substitutes for physical quantity so that "effective quantity" is the product $Q(\omega)y(\omega)$. In contrast, quality $q(\omega)$ complements effective quantity, with the elasticity of substitution between the two governed by the parameter $\rho < 0$. The parameter $\beta \in (0, 1)$ governs the elasticity of substitution between varieties.[23]

Note that each variety has the two quality dimensions. For baby garments in Figure 1(b), style and texture may enter into complementary quality whereas durability and warmth may enter into substitutable quality. In Figure 1(a), bicycle pedals and crank gear with low substitutable quality may be discarded frequently in assembly because they break easily or have the wrong dimensions. These parts with high complementary quality may be lighter to improve the performance of bicycles. For perishables like strawberries, substitutable quality may be the share of non-rotten items in a box, and complementary quality may be their juiciness and sweetness. A durable good, like a machine or a car, that is reliable has high substitutable quality, and one with many accoutrements has high complementary quality.

Technology. Technology is constant returns to scale. One worker at firm ω equipped with an amount $m(\omega)$ of the aggregate Y (from equation (2)) as intermediates can produce a physical amount $y(\omega)$ of output with complementary quality $q(\omega)$ and substitutable quality $Q(\omega)$ according to the functions:[24]

$$y(\omega) = z(\omega)q(\omega)^{-\gamma}m(\omega)^{1-\alpha} \tag{4}$$

$$Q(\omega) = z(\omega)^{\eta}m(\omega)^{\nu}. \tag{5}$$

The term $z(\omega)$ is the overall efficiency of firm ω. The parameter $\gamma > 0$ captures how providing greater complementary quality comes at the cost of physical output per worker $y(\omega)$, given intermediates per worker $m(\omega)$. The parameter $\alpha \in (0, 1)$ governs the elasticity with which more intermediates raise output per worker, given $q(\omega)$. The parameters $\eta > -1$ and $\nu \geq 0$ are the elasticities with which substitutable quality rises with firm efficiency and with intermediates per worker, respectively. Note that, through $m(\omega)$, the quantity and quality of output increase with the quantity and quality of inputs.

Note also that firms separately equip individual workers with material inputs. As a result, the nonhomotheticity in demand for inputs below depends on the wage per worker and not on the firm's total wage bill.

[23] Adding parameters weighting the contribution of individual varieties to the aggregate in (2) would allow the model to accommodate idiosyncratic spending across varieties and countries, as in Eaton et al. (2011). Since we don't look at this dimension of the data we ignore such weights here.

[24] While we cannot eliminate all alternative production functions, two others are worth mentioning. First, a simple generalization incorporates a trade-off in allocating labor to produce more quantity or substitutable quality:

$$y(\omega) = z(\omega)q(\omega)^{-\gamma}\ell m(\omega)^{1-\alpha}$$

$$Q(\omega) = z(\omega)^{\eta}(1-\ell)m(\omega)^{\nu}$$

where $\ell \in [0, 1]$ is the share of time that a worker devotes to producing more physical quantity y and $(1-\ell)$ is the share allocated to producing higher substitutable quality Q. This generalization changes only the constants in the solution to the model below.

Second, assume the two dimensions of quality enter symmetrically in production:

$$y(\omega) = z(\omega)q(\omega)^{-\gamma_1}Q(\omega)^{-\gamma_2}m(\omega)^{1-\alpha}$$

Because quality $Q(\omega)$ and quantity are perfect substitutes in demand, profit maximization with this function yields a corner solution: $Q(\omega) \to 0$ if $\gamma_2 > 1$, $y(\omega) \to 0$ if $\gamma_2 < 1$ and indeterminacy if $\gamma_2 = 1$.

The Buyer's Problem. A buyer with budget x chooses quantity $y(\omega)$ of each variety, taking as given the price $p(\omega)$ per physical unit as well as its two dimensions of quality, $Q(\omega)$ and $q(\omega)$, to maximize (2) subject to the budget constraint:

$$\int_{\omega\in\Omega} p(\omega)y(\omega) \leq x. \tag{6}$$

The first-order condition implies the relationship:

$$\lambda^{-1}Y^{1-\beta}u(\omega)^{\beta-\rho}[Q(\omega)y(\omega)]^{\rho} = p(\omega)y(\omega) \tag{7}$$

where λ is the Lagrange multiplier associated with the budget constraint.

The Producer's Problem. Each firm has a monopoly over its variety ω and takes as given the prices and qualities of other varieties. We first consider the producer's choice of price p, quantity y, and complementary quality q given its unit cost and substitutable quality Q. We then turn to the producer's cost minimization problem determining its unit cost and Q. We consider a single firm so drop the ω argument for now.

Price, output, and complementary quality. Let c denote the production cost per unit of output when $q = 1$, for given Q and m. The firm chooses p, q, and y to maximize gross profit:

$$\max_{p,q,y} y(p - cq^{\gamma}) \tag{8}$$

subject to (7). The solution is:

$$q = \Gamma_1^{1/\rho}Qy \tag{9}$$

$$y = \Gamma_2 \left(\frac{\lambda^{-1}Y^{1-\beta}Q}{c}\right)^{1/(1+\gamma-\beta)} Q^{-1} \tag{10}$$

$$p = \overline{m}cq^{\gamma} \tag{11}$$

where the markup is:

$$\overline{m} = \frac{1+\gamma}{\beta}. \tag{12}$$

Here and below Γ_i, $i = 1, ..., 12$, are constants that are functions of parameters. Appendix C.2 reports their values.[25]

[25]The unit cost cq^{γ} in (8) comes from technology (4). Substituting (7), we write problem (8) as

$$\max_{q,y} \lambda^{-1}Y^{1-\beta}\left[(Qy)^{\rho} + q^{\rho}\right]^{(\beta/\rho)-1}(Qy)^{\rho} - yq^{\gamma}c.$$

The first-order conditions for y and q are, respectively:

$$\lambda^{-1}Y^{1-\beta}\left[(Qy)^{\rho} + q^{\rho}\right]^{(\beta/\rho)-2}(Qy)^{\rho}\left[\beta(Qy)^{\rho} + \rho q^{\rho}\right] = yq^{\gamma}c$$

$$\lambda^{-1}Y^{1-\beta}\left[(Qy)^{\rho} + q^{\rho}\right]^{(\beta/\rho)-2}(Qy)^{\rho}\left[(\beta-\rho)q^{\rho}\right] = \gamma yq^{\gamma}c.$$

Dividing one expression by the other gives (9). Substituting into the problem above, it becomes:

$$\max_{y} (1+\Gamma_1)^{(\beta/\rho)-1}\lambda^{-1}Y^{1-\beta}(Qy)^{\beta} - \Gamma_1^{\gamma/\rho}cQ^{\gamma}y^{1+\gamma}.$$

Since the producer is itself buying varieties as inputs, to complete its problem we need to solve for the buyer's Lagrange multiplier in (7). Substituting q in (9) and y in (10) into Y in (2), incorporating (6) and (7), and integrating across varieties ω, implies that acquiring Y units of the aggregate in (2) requires spending:

$$X(Y) = \Gamma_3 Y^{1+\gamma} V^{-1} \tag{13}$$

where

$$V = \left[\int_{\omega \in \Omega} v(\omega)^{1/(\overline{m}-1)} d\omega \right]^{\overline{m}-1} \tag{14}$$

$$v(\omega) = \frac{Q(\omega)}{c(\omega)}.$$

Here $v(\omega)$ is the inverse of the quality-adjusted cost of variety ω and V is the inverse price index. Because a buyer demands higher complementary quality with more physical quantity, spending X in (13) increases with the aggregate Y with elasticity $1+\gamma$.

Given X and V, the revenue of firm ω with inverse cost $v(\omega)$ is

$$x(\omega) = \left(\frac{v(\omega)}{V} \right)^{1/(\overline{m}-1)} X, \tag{15}$$

the standard CES expression for sales (in terms of substitutable-quality adjusted cost). Combining (15) with (9) and (11), such a firm selling to a buyer with budget x provides complementary quality:

$$q(\omega) = \left(\frac{\Gamma_1^{1/\rho}}{\overline{m}} \right)^{1/(1+\gamma)} \left(\frac{v(\omega)}{V} \right)^{1/(1+\gamma-\beta)} (xV)^{1/(1+\gamma)}. \tag{16}$$

Complementary quality increases with the firm's share in the budget, as reflected in $v(\omega)/V$, and with the buyer's real spending, xV.

Cost minimization and substitutable quality. Since a firm's gross profit is a constant share $(1-1/\bar{m})$ of revenue in (15), maximizing profit is equivalent to maximizing inverse quality-adjusted cost v. A firm with technologies as in (4) and (5) facing a wage w chooses labor ℓ, material inputs m per worker and substitutable quality Q to solve:

$$v^{-1} = \min_{\ell, m, Q} \quad \ell(w + X(m)) \tag{17}$$

subject to

$$Qy \geq 1$$

The first-order condition is:

$$\beta (1+\Gamma_1)^{(\beta/\rho)-1} \lambda^{-1} Y^{1-\beta} Q^\beta y^{\beta-1} - (1+\gamma)\Gamma_1^{\gamma/\rho} c Q^\gamma y^\gamma = 0.$$

Solving for y gives (10). Multiplying this first-order condition by y yields β times total revenue minus $(1+\gamma)$ times total cost as they each appear in the expression for profit before. Hence the markup is $\overline{m} = (1+\gamma)/\beta$.

$$y = \ell z m^{1-\alpha}$$
$$Q = z^{\eta} m^{\nu}.$$

An interior solution requires $\nu < \gamma + \alpha$.[26] Solving (17) gives inverse quality-adjusted cost

$$v(z) = \frac{z^{1+\eta}}{\tilde{c}}$$

where:

$$\tilde{c} = \tilde{\alpha}^{-\tilde{\alpha}}(1-\tilde{\alpha})^{-(1-\tilde{\alpha})} w^{\tilde{\alpha}} (\Gamma_3 V^{-1})^{1-\tilde{\alpha}} \tag{18}$$

indexes input costs and

$$\tilde{\alpha} = \frac{\alpha + \gamma - \nu}{1+\gamma}$$

is the labor share. That is, the ratio of material to labor costs is

$$\frac{X(m)}{w} = \frac{1-\tilde{\alpha}}{\tilde{\alpha}} \tag{19}$$

independent of z, w, or V. The implied substitutable quality is:

$$Q = \left(\frac{1-\tilde{\alpha}}{\tilde{\alpha}} \frac{wV}{\Gamma_3} \right)^{\nu/(1+\gamma)} z^{\eta}. \tag{20}$$

A firm facing higher wages spends more on materials per worker in (19). It buys input varieties with higher complementary quality (buyer spending in (16) becomes $x = X(m)$), and it produces higher substitutable quality in (20).

3.2. *Geography*

There are N countries indexed by n as destinations and by i as sources. Equilibrium outcomes in country i are its wage w_i, inverse price index V_i, and total spending X_i. Each country i has an exogenous endowment L_i of workers and a measure of potential producers with efficiency at least z given by a Pareto measure $T_i z^{-\theta}$. The iceberg cost of moving goods to n from i is d_{ni}.[27]

Consider a potential producer in country i with efficiency z selling to buyers in country n. The inverse of this firm's quality-adjusted cost in the destination is

$$v_{ni}(z) = \frac{z^{1+\eta}}{d_{ni}\tilde{c}_i}, \tag{21}$$

where $\tilde{c}_i$ is given by (18) with $w = w_i$ and $V = V_i$.

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[26] To solve (17), substitute the constraints and use (13) to formulate it as:

$$v^{-1} = \min_m z^{-(1+\eta)} m^{-(1-\alpha+\nu)} (w + \Gamma_3 V^{-1} m^{1+\gamma}).$$

[27] Using firm-level data on exports (excluding sales at home) from a number of countries, Fernandes et al. (2022) explore variants to Eaton et al. (2011) with a lognormal rather than Pareto distribution of efficiencies and with entry costs that vary by source. They find these alternatives deliver a better fit in some dimensions while not making much difference for welfare. Either variant kills any hope of a closed-form price index so we stick with Pareto here.

Entry and Selection. All firms are equally productive in entry. To sell in country n, a firm from any country i incurs a fixed cost f_n. From (15), the zero-profit condition establishes a cutoff:

$$\underline{v}_n = \Gamma_4 \left(\frac{f_n}{X_n}\right)^{\overline{m}-1} V_n \tag{22}$$

such that only producers with $v_{ni}(z) \geq \underline{v}_n$ enter. From (21), the measure of firms in country i that sell in country n is:

$$T_i(d_{ni}\tilde{c}_i\underline{v}_n)^{-\tilde{\theta}}$$

where

$$\tilde{\theta} = \frac{\theta}{1+\eta}.$$

Among firms from i selling in n, the fraction with $v_{ni}(z) \geq v \geq \underline{v}_n$ is

$$\left(\frac{v}{\underline{v}_n}\right)^{-\tilde{\theta}}. \tag{23}$$

Since this distribution is the same regardless of source i, the share of country i's sales in country n's spending is:

$$\pi_{ni} = \frac{T_i(d_{ni}\tilde{c}_i)^{-\tilde{\theta}}}{\Phi_n} \tag{24}$$

where

$$\Phi_n = \sum_{i=1}^{N} T_i(d_{ni}\tilde{c}_i)^{-\tilde{\theta}}.$$

Assume $\overline{m} - 1 > 1/\tilde{\theta}$. Then, integrating (14) over the measures of sellers from different sources in n, using (22) and (23), yields

$$V_n = \Gamma_5 \left(\frac{X_n}{f_n}\right)^{\overline{m}-1-1/\tilde{\theta}} \Phi_n^{1/\tilde{\theta}} \tag{25}$$

Specification of Fixed Costs. Fixed costs use material and labor inputs in the destination country in the same Cobb-Douglas combination as production. The fixed cost of entering market n is:

$$f_n = \kappa_0 \tilde{c}_n L_n^{1+\kappa_1} \tag{26}$$

where κ_0 reflects the overall cost of market entry and κ_1 how it varies with population.

3.3. *Equilibrium*

The economy is in equilibrium if all labor markets clear. Appendix C.3 shows that the labor income is a constant share of absorption. Then, labor markets clear when for all i[28]

$$w_i L_i = \sum_{i=1}^{N} \pi_{ni} w_n L_n.$$

3.4. *The Bilateral Price Equation*

What does our model imply for bilateral prices? Consider a seller from i with efficiency z in market n selling to a buyer with budget x. Its substitutable quality $Q_i(z)$ is given by (20), with $w = w_i$ and $V = V_i$. It doesn't depend on importer features. From (11), setting $c = Q_i(z)/v_{ni}(z)$, the firm's price is:

$$p_{ni}(z,x) = \overline{m}\frac{Q_i(z)}{v_{ni}(z)}[q_{ni}(v_{ni}(z),x)]^{\gamma}, \tag{27}$$

showing how the price rises with substitutable quality $Q_i(z)$ and with complementary quality $q_{ni}(v_{ni}(z),x)$ and falls with the inverse of quality-adjusted cost $v_{ni}(z)$. Complementary quality $q_{ni}(v_{ni}(z),x)$ is in (16) with $V = V_n$, $v(\omega) = v_{ni}(z)$.

To account for selection, we introduce firm ω's relative efficiency in market n as

$$\epsilon_{ni}(\omega) = v_{ni}(z(\omega))/\underline{v}_n, \tag{28}$$

whose distribution, from (23), is Pareto with lower bound one and shape parameter $\tilde{\theta}$. So, it doesn't depend on source or destination characteristics.

Substituting quality measures in (16) and (20) into (27), and replacing z with ϵ using (21) and (22), we relate the bilateral price to exporter and importer characteristics:[29]

$$\begin{aligned} p_{ni}(\epsilon,x) =& \Gamma_6 \left(d_{ni} w_i^{\tilde{\alpha}} V_i^{-(1-\tilde{\alpha})}\right)^{\tilde{\eta}} (w_i V_i)^{\nu(1-\tilde{\gamma})} \left[\left(\frac{f_n}{X_n}\right)^{\overline{m}-1} V_n\right]^{\tilde{\eta}-1} \left(\frac{f_n}{X_n}\right)^{\tilde{\gamma}\bar{m}} (x V_n)^{\tilde{\gamma}} \\ & \times \epsilon^{\tilde{\eta}-1+\tilde{\gamma}\overline{m}/(\overline{m}-1)} \end{aligned} \tag{29}$$

where

$$\tilde{\eta} = \frac{\eta}{1+\eta}$$
$$\tilde{\gamma} = \frac{\gamma}{1+\gamma}.$$

[28]This expression appears in Eaton and Kortum (2002) equations (18) and (19) when there's no service sector, $\alpha = 1$.

[29] Substituting (16) and (20) into (27), we get price as a function of productivity:

$$p_{ni}(z,x) = \Gamma_0 z^{-1} d_{ni} \left(w_i^{\tilde{\alpha}} V_i^{-(1-\tilde{\alpha})}\right) (w_i V_i)^{\nu(1-\tilde{\gamma})} \left(\frac{v_{ni}(z)}{V_n}\right)^{\tilde{\gamma}\overline{m}/(\overline{m}-1)} (x V_n)^{\tilde{\gamma}}$$

where the constant is $\Gamma_0 = \overline{m}^{1-\tilde{\gamma}} \Gamma_1^{\tilde{\gamma}/\rho} \tilde{\alpha}^{-1} \left(\tilde{\alpha}\Gamma_3/(1-\tilde{\alpha})\right)^{(1-\tilde{\alpha})-\nu(1-\tilde{\gamma})}$. To get (29), we replace z with ϵ.

The standard Melitz model emerges when $\eta = \nu = 0$ and $\gamma \to 0$. The price equation then reduces to the inverse of the term in square brackets, a standard selection effect, and ϵ^{-1} the inverse of productivity.

Allowing $\eta > 0$, more efficient firms have a higher substitutable quality, so have a higher price relative to the standard model. For this reason a higher iceberg cost or input cost raises price in the destination (as reflected in the first term in parentheses). For this same reason, the standard Melitz selection effect above is mitigated by the higher substitutable quality of the firms overcoming greater entry barriers.

Allowing $\nu > 0$, a high w_i or V_i induces the producer to use more intermediates per worker, increasing substitutable quality.

Allowing $\gamma > 0$, selling more per buyer is associated with greater complementary quality and hence a higher price. Sales per buyer are greater in a market with a larger entry cost f_n/X_n or richer buyers (xV_n is real spending per buyer).

Looking at Figure 1 through the lenses of equation (29), substitutable quality governs the height of the observations of richer exporters relative to poorer ones, whereas complementary quality governs the slope, how prices increase with importer per capita income. The homothetic expression for trade values in (24) holds despite non-homotheticity in the demand for complementary quality because, in tailoring their varieties to richer buyers, all firms raise their prices with the same elasticity $\tilde{\gamma}$.

To derive an empirical expression for prices from (29), we specify spending per buyer x, and write f_n/X_n and V_n as functions of variables that we can proxy with our data.

Start with spending per buyer x. For final goods, each household gets income from one unit of labor and its share in profits. Appendix C.3 shows that, under balanced trade, spending per household is

$$x_n^C = \left(1 + \frac{1}{\tilde{\alpha}(\tilde{\theta}\overline{m} - 1)}\right) w_n. \tag{30}$$

Turning to intermediates, spending per worker, from (19), is $x_n^F = [(1-\tilde{\alpha})/\tilde{\alpha}]w_n$.

These expressions and (15) imply that all varieties sell in the same proportion to households and firms. The average price of a firm exporting from source i to destination n, with productivity ϵ there, is the following weighted average:

$$\overline{p}_{ni}(\epsilon) = \frac{x_n^C + x_n^F}{x_n^C/p_{ni}(\epsilon, x_n^C) + x_n^F/p_{ni}(\epsilon, x_n^F)} = \Gamma_7 p_{ni}(\epsilon, w_n).$$

We now turn to f_n/X_n and V_n. In Appendix C.3, we show that under balanced trade absorption is proportional to labor income: $X_n = w_n L_n/[\tilde{\alpha}(1 - 1/(\tilde{\theta}\overline{m}))]$. Then, using (18), (25), (26) we write:

$$\frac{f_n}{X_n} = \left[\Gamma_8 \left(\Phi_n^{1/\tilde{\theta}} w_n\right)^{-(1-\tilde{\alpha})} L_n^{\kappa_1}\right]^{\varsigma_1}$$

$$V_n = \Gamma_5 \left(\Gamma_8 L_n^{\kappa_1}\right)^{(1-\varsigma_1)/(1-\tilde{\alpha})} w_n^{\varsigma_1 - 1} \Phi_n^{\varsigma_1/\tilde{\theta}} \tag{31}$$

where

$$\varsigma_1 = \left[1 - (1-\tilde{\alpha})\left(\overline{m} - 1 - \frac{1}{\tilde{\theta}}\right)\right]^{-1}.$$

We assume parameter values that imply $\varsigma_1 > 0$. Substituting into (29), we have:

$$\overline{p}_{ni}(\epsilon) = P_{ni}\epsilon^{\tilde{\eta}-1+\tilde{\gamma}\overline{m}/(\overline{m}-1)}. \tag{32}$$

where

$$P_{ni} = \Gamma_9 d_{ni}^{\tilde{\eta}} S_i D_n$$

is common to all exporters to n from i and S_i and D_n are exporter and importer characteristics given by:

$$\begin{aligned} S_i &= w_i^{\delta_w^S} \Phi_i^{\delta_\Phi^S} L_i^{\delta_L^S} \\ D_n &= w_n^{\delta_w^D} \Phi_n^{\delta_\Phi^D} L_n^{\delta_L^D} \end{aligned} \tag{33}$$

where:

$$\begin{aligned} \delta_w^S &= \tilde{\eta} + \varsigma_1\varsigma_2 & \delta_w^D &= \varsigma_1\varsigma_3 \\ \delta_\Phi^S &= \frac{\varsigma_1\varsigma_2}{\tilde{\theta}} & \delta_\Phi^D &= \frac{\varsigma_1\varsigma_3}{\tilde{\theta}} - \frac{1}{\theta} \\ \delta_L^S &= \kappa_1\varsigma_2\frac{1-\varsigma_1}{1-\tilde{\alpha}} & \delta_L^D &= \frac{\kappa_1}{1-\tilde{\alpha}}\left(-\varsigma_1\varsigma_3 + \tilde{\gamma}\right) \end{aligned}$$

and where:

$$\begin{aligned} \varsigma_2 &= \nu(1-\tilde{\gamma}) - \tilde{\eta}(1-\tilde{\alpha}) \\ \varsigma_3 &= \tilde{\gamma} + (1-\tilde{\alpha})\left(\frac{1}{\theta} - \tilde{\gamma}\overline{m}\right). \end{aligned}$$

We use equation (32) to estimate bilateral prices. The coefficient on iceberg costs corresponds to $\tilde{\eta}$, the effect of firm efficiency on substitutable quality. It captures how more efficient firms select into more remote markets, as in Johnson (2012). The effects of importer and exporter wages on prices through selection, material inputs and non-homothetic demand discussed in (29) are still present. Now in addition, wages, population and market access Φ_i influence prices in more intricate ways through the price indices V_n and entry cost relative to market size f_n/X_n in (31).

Price and quality. As in other papers on trade and quality differentiation, prices in our model reflect both quality and efficiency. To make this connection at the variety level we combine the two dimensions of quality, as they appear in equation (27), into the term:

$$\Theta_{ni}(v_{ni}(z), x) = Q_i(z)q_{ni}((v_{ni}(z), x))^{\gamma}.$$

We then use (15) and (27) to write:

$$\log\Theta_{ni}(v_{ni}(z), x) = \log p_{ni}(z, x) + (\bar{m}-1)\log x_{ni}(z, x) + \log\left(\bar{m}^{-1}V_n X_n^{1-\bar{m}}\right).$$

Khandelwal (2010), equation (14), and Khandelwal et al. (2013), equation (7), provide similar expressions for their single dimension of substitutable quality. It reflects how, given quality, prices vary with sales as they're affected by unit cost.

Aggregating to the level of bilateral trade, we define country i's average substitutable quality as:

$$\bar{\Theta}_i = \bar{Q}_i T_i^{\eta/\theta}$$

where:

$$\bar{Q}_i = \left(\frac{1-\tilde{\alpha}}{\tilde{\alpha}} \frac{w_i V_i}{\Gamma_3} \right)^{\nu/(1+\gamma)}$$

relates quality to input costs, common to all firms from i, while $T_i^{\eta/\theta}$ reflects the average firm-specific quality. We can then write:

$$\log \bar{\Theta}_i = \log P_{ni} + \frac{\eta}{\theta} \log X_{ni} + H_n \tag{34}$$

where:

$$H_n = -\log \left[\Gamma_{10} \left(\frac{X_n}{\Phi_n} \right)^{\eta/\theta} D_n \right]$$

is an importer fixed effect. Again, the average price of exports to n from i relates both to overall exporter quality Θ_i and to total sales to that market X_{ni}. As shown by equation (23), there's no variation in quality-adjusted cost v_{ni} across sources in a destination. Hence if η = 0 all variation in prices reflects differences in substitutable quality. With $\eta > 0$, firm selection generates a positive relationship between bilateral sales and quality.

3.5. *Products and Extensive Margins*

Our model has the same implications for the extensive margins of *varieties* as the Melitz model. For one thing, a variety has at most one exporter. A feature of the trade data, at any available level of aggregation, is that there are multiple exporters per product. We reconcile the difference by treating products in the data as random collections of varieties in the model.

We assume a unit continuum of products indexed by k. The probability that a variety belongs to product $K \leq k$ is:

$$F(k) = k^{\kappa_2} \tag{35}$$

where $\kappa_2 > 1$. The number of varieties from i in product k with efficiency $Z \geq z$ is distributed Poisson with parameter:

$$dF(k) T_i z^{-\theta}.$$

Country i exports a variety with efficiency z to country n if $z^{1+\eta} \geq d_{ni}\tilde{c}_i \underline{v}_n$. Then, the number of varieties of product k that country i exports to n is distributed Poisson with parameter $dF(k)T_i(d_{ni}\tilde{c}_i\underline{v}_n)^{-\tilde{\theta}}$. The probability that country i exports product k to country n is the probability of more than zero varieties. Using equations (22), (24), and (31) this probability is:

$$\mu_{ni}(k) = 1 - \exp\left[-\Gamma_{11} k^{\kappa_2 - 1} \left(w_n \Phi_n^{1/\tilde{\theta}} \right)^{\varsigma_1(1-\tilde{\alpha})} L_n^{-\kappa_1 \varsigma_1} \pi_{ni} \right]. \tag{36}$$

The term in brackets is negative the expected number of varieties that country i exports to n in product k. It increases with the trade share π_{ni} and with importer characteristics w_n, Φ_n and L_n (estimated $\kappa_1 < 0$), and it decreases with the level of fixed costs κ_0 (in the constant

Γ_{11}). The extensive margin at the product level $\mu_{ni}(k)$ is a concave function of this extensive margin at the variety level. This concavity helps the model capture the non-linearities described in Section 2.3 above.

In (35), κ_2 increases the heterogeneity in the number of varieties per product. To see its role, consider Figure 2 above. Only if some products have a lot of varieties can the extensive margin of exporting be close to 0.2 for small countries, with tiny trade shar es in all destinations. But if all products were large, then the extensive margin of exporting and importing would be close to one for all middle-sized and large countries.

The probability that country n imports product k from at least one exporter is:

$$\mu_{n\cdot}(k) = 1 - \prod_{i \neq n} (1 - \mu_{ni}(k)) \,.$$

The probability that country i exports product k is:

$$\mu_{\cdot i}(k) = \max_{n \neq i} \{\mu_{ni}(k)\}.$$

The probability that product k is internationally traded is:

$$\mu_{\cdot}(k) = 1 - \prod_{i=1}^{N} (1 - \mu_{\cdot i}(k)) \,.$$

Denote the share of internationally-traded products that country n imports from country i as E_{ni}, the share of products that country n imports from any source as $E_{n\cdot}$, and the share of products that country i exports to any destination as $E_{\cdot i}$. These shares are:

$$E_{ni} = \int_{k \in (0,1)} \mu_{ni}(k) [\mu_{\cdot}(k)]^{-1} dk,$$

$$E_{n\cdot} = \int_{k \in (0,1)} \mu_{n\cdot}(k) [\mu_{\cdot}(k)]^{-1} dk,$$

$$E_{\cdot i} = \int_{k \in (0,1)} \mu_{\cdot i}(k) [\mu_{\cdot}(k)]^{-1} dk. \tag{37}$$

Our model relates to the various components of trade data as follows: equation (24) gives us trade shares; equation (32) gives us prices; and equations (37) give us the extensive margins. We now use these relationships to estimate the parameters of the model.

4. ESTIMATION

We proceed in two stages. The first stage estimates a gravity equation that delivers terms for bilateral resistance (the $d_{ni}^{-\tilde{\theta}}$'s) and multilateral resistance (the Φ_n's). These terms serve as inputs into the second stage, which dissects trade values into margins.

4.1. *Trade Flows and Multilateral Resistance*

We use data on trade flows, GDP, and distance to estimate a gravity equation based on equation (24). We construct trade shares as:

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

for $i \neq n$ and:

$$\pi_{nn} = \frac{1}{X_n}\left(X_n - \sum_{i' \neq n} X_{ni'}\right),$$

where X_n is country n's total absorption.[30] We parameterize bilateral resistance as proportional to distance

$$\log(d_{ni}^{-\tilde{\theta}}) \propto \delta^g \log(dist_{ni}) \tag{38}$$

for $i \neq n$, where $dist_{ni}$ is the distance between n and i and δ^g is a parameter to be estimated. We estimate the d_{nn} individually as country fixed effects.

For all $i \neq n$, we regress:

$$\log\left(\frac{\pi_{ni}}{\pi_{nn}}\right) = A_n + B_i + \delta^g \log dist_{ni} + \varepsilon_{ni}^X, \tag{39}$$

where A_n is an importer fixed effect, B_i is an exporter fixed effect, and ε_{ni}^X is the residual.[31] Equivalent to Waugh (2010), and in contrast to Eaton and Kortum (2002), we attribute country-level differences in openness to differences in internal trade costs (d_{nn}). Under this interpretation, equation (24) implies that fixed effects correspond to:

$$A_n = -\log\left(T_n\tilde{c}_n^{-\tilde{\theta}}\right) - \log(d_{nn}^{-\tilde{\theta}})$$
$$B_i = \log\left(T_i\tilde{c}_i^{-\tilde{\theta}}\right).$$

A consistent estimate of Φ_n is then

$$\hat{\Phi}_n = \exp(-\hat{A}_n) + \sum_{i \neq n} \exp(\hat{B}_i + \hat{\delta}^g \log dist_{ni}), \tag{40}$$

where $\hat{x}$ denotes the estimate of x.

Estimating the gravity equation (39) yields destination A_n and source B_i fixed effects and $\hat{\delta}^g = -1.60$ (standard error 0.028). We use these estimates to construct measures of multilateral resistance, ($\hat{\Phi}_n$), bilateral resistance ($\widehat{\log d_{ni}^{-\tilde{\theta}}} = \hat{\delta}^g \log(dist_{ni})$ for $n \neq i$), and trade shares ($\hat{\pi}_{ni}$), to estimate the remaining parameters of the model, as described next.

[30]While we've assumed balanced trade elsewhere, our trade share measures take deficits into account. As shown in Appendix C.3, our model implies that a country's absorption X_n depends on its GDP and deficit Δ as follows:

$$X_n = \frac{\tilde{\theta}\overline{m}}{\tilde{\alpha}\tilde{\theta}\overline{m} + 1 - \tilde{\alpha}} GDP_n + \frac{\tilde{\alpha}\tilde{\theta} + 1}{\tilde{\alpha}\tilde{\theta}\overline{m} + 1 - \tilde{\alpha}}\Delta_n.$$

In constructing our absorption measure we approximate this expression numerically as $X_n = GDP_n/.5 + \Delta_n$, which we show in Appendix C.3 is a good approximation given our parameter estimates from the second stage.

[31]For reasons discussed in Anderson and Van Wincoop (2003), we treat ε_{ni}^X as measurement error. A structural error in $d_{ni}^{-\tilde{\theta}}$ would spill over to all error terms through general equilibrium.

4.2. *Prices and Extensive Margins*

We estimate the vector of parameters $\Xi = \{\gamma, \eta, \nu, \theta, \beta, \kappa_0, \kappa_1, \kappa_2\}$ to fit the price and the extensive margins, fixing the labor share at $\tilde{\alpha} = 0.5$.[32] From (32), we specify the bilateral price term as the function:

$$\log P_{ni}(\Xi) = \delta_0 + \delta^G \widehat{d_{ni}^{-\tilde{\theta}}} + S_i + D_n \tag{41}$$

where S_i and D_n are the exporter and importer effects in (33), $\delta^G = -\eta/\theta$ and δ_0 is a constant. Similarly, equations (37) specify the extensive margins as functions of Ξ. From the first stage gravity equation, we use the estimates for $\widehat{d_{ni}^{-\tilde{\theta}}}$, $\hat{\Phi}_n$, and $\hat{\pi}_{ni}$. From the data, we use population for L_i and income per capita as a proxy for w_i.

We choose Ξ to minimize:

$$\begin{aligned} \mathcal{W}(\Xi) =& \frac{1}{V(\log P_{ni}^{\text{data}})} \sum_{n=1}^{N} \sum_{i \neq n, i=1}^{N} \upsilon_{ni} \left(\log P_{ni}^{\text{model}}(\Xi) - \log P_{ni}^{\text{data}}\right)^2 \\ &+ \frac{1}{N_E V(\log E_{ni}^{\text{data}})} \sum_{n=1}^{N} \sum_{i \neq n, i=1}^{N} \left(\log E_{ni}^{\text{model}}(\Xi) - \log E_{ni}^{\text{data}}\right)^2 \\ &+ \frac{1}{N V(\log E_{\cdot i}^{\text{data}})} \sum_{i=1}^{N} \left(\log E_{\cdot i}^{\text{model}}(\Xi) - \log E_{\cdot i}^{\text{data}}\right)^2 \\ &+ \frac{1}{N V(\log E_{n \cdot}^{\text{data}})} \sum_{n=1}^{N} \left(\log E_{n \cdot}^{\text{model}}(\Xi) - \log E_{n \cdot}^{\text{data}}\right)^2 \end{aligned} \tag{42}$$

where $V(x)$ is the variance of variable x in the data. Section 2 describes all the data moments. Price index weights υ_{ni} are proportional to the number of products with price data that country n imports from country i. The number of importer-exporter pairs with price data is $9,455$; the number of importer-exporter pairs whose extensive margin of trade is observed and not zero is $N_E = 9,555$; the number of countries is $N = 100$.

To minimize $\mathcal{W}$, we iterate over guesses of Ξ using a combination of simulated annealing and the simplex algorithm. For each guess of Ξ, we calculate the integrals of the extensive margins in equations (37) numerically. We are choosing eight parameters to fit 19,210 observations.

4.3. *Results*

The top panel of Table IV reports the parameter values that minimize $\mathcal{W}$, along with their standard errors.[33] The parameter values are all significant and have the expected signs. The trade elasticity in the model is $\tilde{\theta} = \theta/(1+\eta)$ which, calculated at the point estimates, is 5.82, in line

[32]In Appendix F.1 repeats the estimation of margins with $\tilde{\alpha} = 0.4$ and $\tilde{\alpha} = 0.6$. This parameter is not identified and hence the fit of the model does not change. For robustness, we also re-estimate the model with data from 2017. Parameter κ_0 decreases from 0.71 to 0.09 to account for the larger extensive margins in 2017. Quality plays a larger role in the welfare gains from trade due to a higher estimate of η.

[33]Appendix D.1 details the procedure to estimate standard errors. We allow for the clustering of observations with the same importer or the same exporter, and for heteroskedasticity in prices. The estimation also accounts for the attenuation bias in the coefficients on Φ_n due to measurement error in the first stage.

TABLE IV

PARAMETER ESTIMATES

	parameter	std. dev.
γ	0.146	0.014
η	0.490	0.058
ν	0.085	0.009
θ	8.678	0.702
β	0.557	0.005
κ_1	-0.423	0.007
κ_2	5.107	0.045
$\tilde{\kappa}_0{}^*$	0.714	0.131
	num. observations	R-squared
$\log \overline{P}_{ni}$	9455	0.47
$\log E_{ni}$	9555	0.38
$\log E_{n\cdot}$	100	0.19
$\log E_{\cdot i}$	100	0.65

See Appendix D.1 for the estimation of standard deviation. $^*\tilde{\kappa}_0 = \kappa_0 \tilde{\alpha}^{-\tilde{\alpha}}[\Gamma_3^{-1}(1-\tilde{\alpha})]^{-(1-\tilde{\alpha})}$.

with estimates from other studies.[34] The fixed cost of entry rises with destination population with an elasticity of $1+\kappa_1 = 0.58$ (higher than Eaton et al. (2011)'s estimate of 0.35). The elasticity of substitution between varieties implied by β is 2.3. It has a similar magnitude to the median estimate of the elasticity of substitution between products from different countries, 2.1 in Soderbery (2015) (for HS8 categories) and 2.7 in Broda and Weinstein (2006) (for SITC-5 categories).

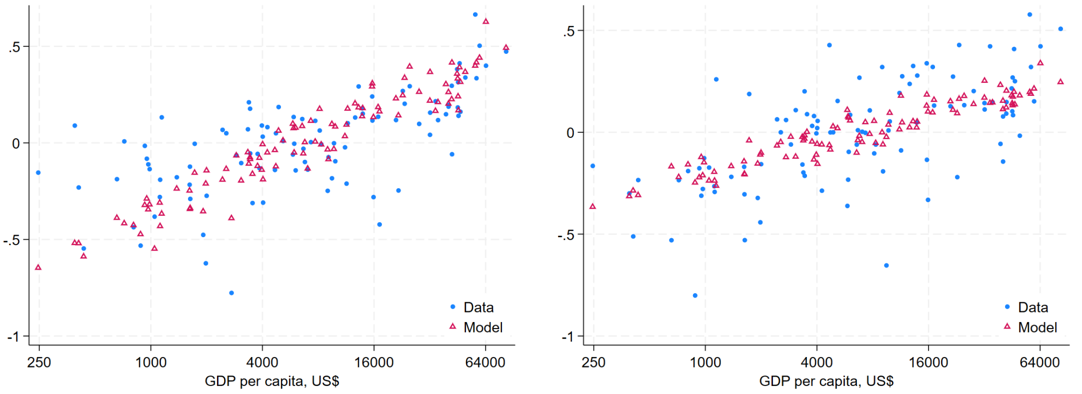
The production function parameters η, ν, and γ that distinguish our predictions for prices from Melitz (2003) in (29) are all positive and significant. Firm productivity increases substitutable quality with an elasticity $\eta = 0.49$. Then, the price of goods sold from sources with high costs $d_{ni}\tilde{c}_i$ is higher because only productive firms sell from these sources. This selection effect is the only effect of trade costs d_{ni} on prices, and it explains why prices decrease with exporter population. Larger countries' access to a greater range of varieties decreases input costs $\tilde{c}_i$. For exporter wages w_i, this selection effect is small.[35] The main effect is that firms faced with high real wages $w_i V_i$ buy more material inputs per worker raising substitutable quality with an elasticity $\nu = 0.085$. Across destinations, prices increase with real wages $w_n V_n$ with an elasticity $\tilde{\gamma} = 0.13$ as a result of the non-homotheticity in the demand for complementary quality.

These parameters have implications for firm-level data. Within firms across destinations, output prices increase with importer per capita income also with an elasticity $\tilde{\gamma} = 0.13$. Estimates in the literature are lower, ranging from 0.015 to 0.026.[36] Appendix C.4 shows that our estimat-

[34]Head and Mayer (2014)'s meta analysis reports a mean elasticity, based on tariff and freight rates (most compatible conceptually with our model here), of 5.03. The identification of the trade elasticity $\tilde{\theta}$ here is subtle because it influences the price and extensive margins in several ways. For example, destination market access $\Phi_n^{1/\tilde{\theta}}$ increases import variety and decreases import prices through selection.

[35]Using (31), we can quantify the effect of each mechanism discussed in (29) on the price coefficients of the estimating equation (32). See Appendix D.2 for the full decomposition.

[36]See Manova and Zhang (2012) (Table VII), Görg et al. (2017) (Table 2), and Fan et al. (2020) (Table 1). The expression for prices within firms is in footnote 29, where we take these papers' control for importer price indices as absorbing V_n. Within firms across destinations, the elasticity of *CIF prices* with respect to distance in the model is $-(\delta^G/\tilde{\theta})[1-\tilde{\gamma}\bar{m}/(\bar{m}-1)] = 0.21$. We expect this elasticity to be higher than for *FOB prices* which ranges from 0.053 to 0.009 in these papers.



(a) Exporter FE

(b) Importer FE

FIGURE 3.—Fixed effects from price regression

ing equations, for trade flows and margins, arise in a model with heterogeneous skills within countries. There, input prices rise with firm wages with an elasticity $\tilde{\gamma} = 0.13$, compared to 0.16 in Fieler et al. (2018) (Table 2), and input prices rise with domestic sales with an elasticity 0.020, compared to 0.011 in Kugler and Verhoogen (2011) (Table I.B).[37]

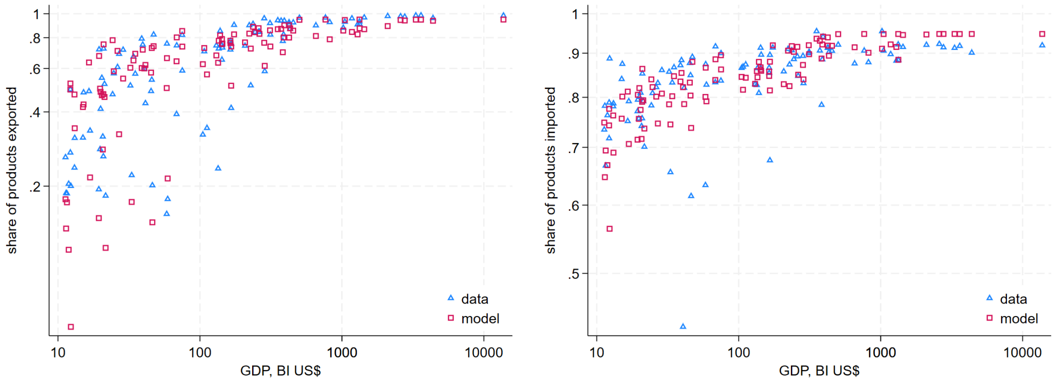
The bottom panel of Table IV reports how well the model fits each of the four components of the objective function $\mathcal{W}$. The R^2 of the price component 0.47 is almost the same as that of the descriptive price regression in Table II column (5), with the same weights as the estimation. For the bilateral extensive margin E_{ni}, the R^2 in the model 0.38 is lower than the corresponding regression in Table I ($R^2 = 0.64$ as reported in Table A.IV). Our worse performance isn't surprising since our estimation targets the bilateral margin (E_{ni}) as well as importing and exporting margins $E_{n\cdot}$ and $E_{\cdot i}$.

Figure 3 shows the relationship between per capita GDP (on the x-axes) and the importer and exporter fixed effects from the price regressions (on the y-axes) in the data and in the model. We perform the same variance decomposition of the predicted $\log P_{ni}$ as we did of the actual $\log P_{ni}$ reported in Section 2: Exporter fixed effects account for 0.78 of the variance, importer fixed effects account for 0.24, and distance accounts for 0.12. The corresponding numbers in the data are 0.56, 0.33, and 0.21. Hence our model puts more emphasis on exporter variation than it accounts for in the data.

Figure 4 shows our model's predictions for the extensive margins of exporting and importing in comparison with the data. The x-axes measure total GDP and the y-axes the fraction of total products exported or imported. In both cases our model captures the slope and curvature of the relationships but misses the large oil countries that fail to expand their range of exports or imports in line with their GDP's.

Table V shows that our model replicates quite closely the decomposition of trade flows into margins presented in Section 2, Table I. We argued earlier that measurement error may bias the price regression in the data. The model's price regression is closer to the regression in Table

[37] This extension adds two parameters to the model that allows us to match the elasticity of output prices with respect to sales and of wages with respect to sales across firms within countries, which we take from Verhoogen (2008).



(a) Exporting (b) Importing

FIGURE 4.—Extensive margins

TABLE V

DECOMPOSITION OF TRADE FLOWS INTO MARGINS

	data				model			
dependent variable →	X_{ni}	E_{ni}	Y_{ni}	$\overline{P}_{ni}$	X_{ni}	E_{ni}	Y_{ni}	$\overline{P}_{ni}$
exporter GDP	1.35	0.88	0.45	0.02	1.37	0.84	0.47	0.05
importer GDP	1.10	0.40	0.66	0.04	1.01	0.49	0.59	0.03
distance	-1.18	-0.72	-0.52	0.06	-1.18	-0.65	-0.58	0.04
exporter GDP per capita	1.34	0.92	0.32	0.10	1.36	0.85	0.33	0.17
exporter population	1.35	0.85	0.55	-0.05	1.37	0.83	0.59	-0.06
importer GDP per capita	1.08	0.45	0.51	0.12	0.97	0.52	0.48	0.10
importer population	1.12	0.35	0.79	-0.02	1.05	0.46	0.68	-0.02
distance	-1.19	-0.68	-0.63	0.12	-1.20	-0.63	-0.67	0.11
number of observations	9,455	9,455	9,455	9,455	9,455	9,455	9,455	9,455

Note: The table compares the predictions of the model to the moments from the data in Table I. We report standard errors in Appendix Table A.IV.

II column (5) that gives less weight to the observations where we expect larger measurement errors.

We've treated products as collections of varieties, with the parameter κ_2 governing heterogeneity in the number of varieties per product. We've estimated κ_2 to target the extensive margins of trade, i.e., the number of products per exporter, importer, and importer-exporter dyad. But unobserved heterogeneity in the number of varieties per product also generates observed heterogeneity in the number of exporters per product, a moment which we haven't targeted. Table VI shows how well our predictions for this moment compare with the data.[38]

[38]In the model, we calculate the number of exporters at the k^{th} percentile of the product distribution as $\sum_{i=1}^{N} \mu_{\cdot i}(k)$. We can't apply the analogous formula for importers because trade flows are correlated across importers as they're affected by the same exporters' idiosyncratic productivity draws.

TABLE VI

DISTRIBUTION OF THE NUMBER OF EXPORTERS PER PRODUCT

	percentile of the distribution					
	10%	25%	50%	75%	90%	**mean**
data	35	51	68	81	91	**65**
model	13	47	78	90	94	**66**

5. GAINS AND THEIR COMPOSITION

Having estimated the parameters of the model we now look at overall welfare gains from trade and economic growth and how these gains break down into a greater range of goods available, a lower price per good or a higher quality.

5.1. *Gains and the ACR Formula*

Inverting the expenditure function (13), a representative household in country n spending x_n^C obtains an aggregate $Y_n^C = (\Gamma_3^{-1} V_n x_n^C)^{1/(1+\gamma)}$. Under balanced trade, we can use (30) and apply a monotonic transformation to get an expression for utility:

$$U_n = w_n V_n. \tag{43}$$

Using (18), (25), and (24) with $i = n$, substituting (31) into (43), delivers:

$$U_n = \Gamma_{12} \left(L_n^{\kappa_1 \left[1 - \tilde{\theta}(\overline{m} - 1)\right]} \cdot \frac{T_n d_{nn}^{-\tilde{\theta}}}{\pi_{nn}} \right)^{1/\left[\tilde{\theta} - (1-\tilde{\alpha})(\tilde{\theta}\bar{m} - 1)\right]}.$$

This expression for utility takes the same form as the one given by ACR for the Melitz model with intermediates on their page 115. Since our formula is in levels rather than changes, country n's technology T_n, internal transport costs d_{nn}, and scale L_n enter. With our negative estimate of κ_1, fixed costs rise less than in proportion to market size, so that living in a larger market confers an advantage.

That our model satisfies the conditions for the ACR formula shouldn't be a surprise. The three restrictions in their theorem on the gains from trade apply to trade volumes. Equation (24) above shows that trade volumes in our model correspond to those in the standard trade models they consider. Hence our model has the same implications for how external shocks affect welfare and trade volumes as standard models. What we add is how volumes decompose into the price, quantity, and variety margins, and how welfare decomposes into variety, physical cost, and quality.

5.2. *Decomposing Gains*

As in Dekle et al. (2007), we denote the counterfactual value of any variable x as x' and its change as $\hat{x} = x'/x$. Let $\mathcal{M}_n$ be the measure of varieties consumed in country n. Using equations (14) and (23), we write the welfare change from a shock as

$$\hat{U}_n = \hat{\mathcal{M}}_n^{\bar{m}-1} \hat{w}_n \hat{\underline{v}}_n \tag{44}$$

TABLE VII

DECOMPOSITION OF WELFARE CHANGES

	Range of varieties $\left(\mathcal{M}_n^{\bar{m}-1}\right)$	Inverse physical cost $\left(\frac{w_n \underline{v}_n}{\bar{Q}_n}\right)$	Substitutable quality $\left(\bar{Q}_n\right)$
Uniform worldwide growth	0.53	0.41	0.066
Welfare differences across countries	0.54 (0.03)	0.36 (0.02)	0.098 (0.01)
Gains from trade	0.53	0.29 (0.08)	0.18 (0.08)

Note: The table displays the average contribution of each component of welfare relative to total for the two counterfactual exercises and the cross-country welfare comparison described in the text. In each row, the columns add to one. Where standard errors are not zero, they appear in parenthesis.

The first term, the welfare gain from a greater range in varieties, may be written as:[39]

$$\hat{\mathcal{M}}_n^{\bar{m}-1} = \hat{U}_n^{(1-\tilde{\alpha})(\bar{m}-1)} \hat{L}_n^{-\kappa_1(\bar{m}-1)}. \tag{45}$$

For any shock to technology, trade costs or *foreign* labor forces, the share of the welfare gain taking the form of increased range is $(1-\tilde{\alpha})(\bar{m}-1)$. The point estimates of our parameters in Table IV give a value of 0.53, meaning that a lower effective cost per variety and a greater range of varieties each contribute about equally to the overall gains. To the extent that a shock increases the domestic labor force ($\hat{L}_n > 1$), the contribution of the range of varieties to welfare is larger, given our negative estimate for κ_1.

Note that the exponents of w_n, Φ_n, and L_n in (36), used to identify the extensive margins, don't enter (45). These exponents govern the *magnitude* of $\hat{\mathcal{M}}_n$ but not its *share* in welfare because $\hat{\mathcal{M}}_n$ increases $\hat{U}_n$ directly in (44) and indirectly through the effect of the price index $\hat{V}_n$ on the inverse quality-adjusted cost $\hat{w}_n \hat{\underline{v}}_n$.

We further decompose effective cost $\hat{w}_n \hat{\underline{v}}_n$ into quality and physical cost. Define the average quality in a destination n, $\bar{Q}_n$, as the quality that would give its households their utility U_n if all varieties had substitutable quality $\bar{Q}_n$ and their same physical cost $Q_i(z)/v_{ni}(z)$.[40] Appendix E.1 shows that in changes

$$\hat{\bar{Q}}_n = \hat{\underline{v}}_n^{\tilde{\eta}} \left[\frac{\sum_i \pi'_{ni} (d'_{ni} \tilde{c}'_i)^{\tilde{\eta}/(1-\bar{m})} (w'_i V'_i)^{\nu(1-\tilde{\gamma})/(1-\bar{m})}}{\sum_i \pi_{ni} (d_{ni} \tilde{c}_i)^{\tilde{\eta}/(1-\bar{m})} (w_i V_i)^{\nu(1-\tilde{\gamma})/(1-\bar{m})}} \right]^{1-\bar{m}}. \tag{46}$$

The term $\hat{\underline{v}}_n^{\tilde{\eta}}$ captures the selection of more productive firms into markets with high entry cutoffs $\underline{v}_n$, and the term in brackets captures the heterogeneity in quality across exporters, due also to selection ($d_{ni}\tilde{c}_i$ term) and to material inputs ($w_i V_i$ term).

The magnitude of changes in substitutable quality $\hat{\bar{Q}}_n$ relative to inverse physical cost $\hat{w}_n \hat{\underline{v}}_n / \hat{\bar{Q}}_n$ depends on the nature of individual shocks. We consider three exercises summarized in Table VII. Mathematical details are in Appendix E.

[39] From section 3.2, $\mathcal{M}_n = \Phi_n \underline{v}_n^{-\tilde{\theta}}$. Substituting $\underline{v}_n$ with (22) and (25), we get $\hat{\mathcal{M}}_n = \hat{f}_n / \hat{X}_n$. Manipulating (31) then gives us (45).

[40] The physical cost here has complementary quality normalized $q = 1$. The complementary quality consumed is proportional to effective quantity Qy in (9) and so its effect on welfare is subsumed in $\hat{w}_n \hat{\underline{v}}_n$.

Uniform growth The case of a uniform worldwide productivity improvement delivers closed-form solutions. Assume $\hat{T}_n = \hat{T} > 1$ with $\hat{L}_n = \hat{d}_{ni} = 1$ for all n and i. In such a counterfactual relative wages and trade shares don't change ($\hat{w}_i = \hat{\pi}_{ni} = 1$) while every country experiences the same proportional increase in its inverse price index $\hat{V}_n = \hat{V} = \hat{T}^{1/[\tilde{\theta}-(1-\tilde{\alpha})(\tilde{\theta}\bar{m}-1)]}$, which is also each country's welfare gain ($\hat{U}_n = \hat{U} = \hat{V}$). The contribution of substitutable quality to welfare is $\hat{\bar{Q}}_n = \hat{\bar{Q}} = \hat{U}^{\nu(1-\tilde{\gamma})+\tilde{\eta}[1-\bar{m}(1-\tilde{\alpha})]}$. At the parameter estimates, the contributions of the range of goods, of average quality, and of physical costs are 0.53, 0.066, and 0.41 respectively. Quality plays a small role.

Welfare differences across countries To what extent do richer countries have a greater range of goods, lower physical costs relative to wages, or higher average quality? To answer this question, we calculate the real income, $U_n/U_0 = w_n V_n/(w_0 V_0)$, the range of varieties $\mathcal{M}_n/\mathcal{M}_0$ and the average substitutable quality $\bar{Q}_n/\bar{Q}_0$ relative to a reference country 0 with our parameter estimates from Table IV, the estimates for Φ_n, π_{ni} and $d_{ni}^{-\tilde{\theta}}$ from gravity, and data on population L_n and income per capita to proxy for w_n.[41]

On average, the range of goods consumed accounts for 0.54 of the welfare differences across countries, the physical cost component accounts for 0.36 and substitutable quality accounts for 0.098. These averages are similar to the counterfactual of uniform growth above, but here they vary across countries. Countries with a larger population tend to enjoy a greater range of products, and countries with good market access (a high Φ_i) have lower physical costs relative to wages.

International trade We decompose the real income gains of moving from autarky to the estimated model. For autarky, we take $\hat{d}_{ni} \to \infty$ and $\hat{d}_{nn} = 1$. The range of goods component accounts for 0.53 of the gains from trade, following equation (45). On average, the decrease in physical cost accounts for 0.29 of the gains from trade and substitutable quality accounts for 0.18. The role of quality is larger than in the exercises above because of selection. Conditional on entry, imported goods have the same distribution of quality-adjusted costs $v_{ni}(z)$ as domestic goods (equation (23)), but to overcome trade costs d_{ni} imported goods have higher productivity z and hence higher substitutable quality.

So far, we've discussed the range of goods at the unobserved variety level and not the observed HS6 product level. Unlike varieties, our predictions for the product level depend on the nature and magnitude of the shock. To illustrate the difference, consider again a uniform worldwide improvement in technology $\hat{T}_n = \hat{T} > 1$, and assume a change that delivers a 10 log point change in utility. At the variety level, the shock expands the range of goods traded in all directions in the same proportion, by 5 log points. The expansion in the range of HS6 products traded is much lower: The increase is 3.26 log points (s.e. 1.73) per importer-exporter pair ($\hat{EM}_{ni}$), 0.25 log points (s.e. 0.15) per importer ($\hat{EM}_n$), and 0.94 (s.e. 1.14) per exporter ($\hat{EM}_i$). The change per importer is the smallest since most countries already import most products. So new varieties are classified into previously imported HS6 categories. The conclusion is that, at the level of HS6 products, growth has much less effect on the range of what's traded and correspondingly more on the quantities traded.

[41] The decomposition of welfare into margins is independent of the reference country (Appendix E.3).

6. CONCLUSION

The Comtrade data on bilateral trade provide one of the most comprehensive pictures of how spending breaks down into the quantity, quality, and range of goods exchanged between a broad range of sellers and buyers. Some striking regularities emerge. We've provided a parsimonious formulation of preferences and technology to integrate these data into a quantitative general equilibrium framework. Our approach applies this decomposition both to final spending and to spending on intermediates, explaining patterns in the data in terms of a small number of parameters of preferences and technology.

The analysis implies that the gains from trade can be inferred from the home trade share and a trade elasticity, as in a broad class of trade models that don't account for the decomposition that we do here. Moreover, our estimate of the trade elasticity is in line with estimates from this literature. Our results suggest that about half of buyers' gains from trade and growth come from an expansion in the range of available varieties. But aggregation of varieties into coarser product categories gives the appearance of more gains at the intensive margin. Quality plays a larger role in the gains from international trade than from economic growth because, through selection, imported varieties typically have higher quality than domestic ones.

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