MEASURING THE UNEQUAL GAINS FROM TRADE*

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Individuals that consume different baskets of goods are differentially affected by relative price changes caused by international trade. We develop a methodology to measure the unequal gains from trade across consumers within countries. The approach requires data on aggregate expenditures and parameters estimated from a nonhomothetic gravity equation. We find that trade typically favors the poor, who concentrate spending in more traded sectors. *JEL* Codes: D63, F10, F60.

I. Introduction

Understanding the distributional impact of international trade is one of the central tasks pursued by international economists. A vast body of research has examined this question through the effect of trade on the distribution of earnings across workers (e.g., Stolper and Samuelson 1941). A second channel operates through the cost of living. It is well known that the consumption baskets of high- and low-income consumers look very different (e.g., Deaton and Muellbauer 1980b). International trade therefore has a distributional impact whenever it affects the relative price of goods that are consumed at different intensities by rich and poor consumers. For example, a trade-induced increase in the price of food has a stronger negative effect on low-income consumers, who typically have larger food expenditure shares than do richer consumers. How important are the distributional effects of international trade through this expenditure channel? How do they vary across countries? Do they typically favor high- or low-income consumers?

In this article we develop a methodology to answer these questions. The approach is based on aggregate statistics and model parameters that can be estimated from readily available bilateral trade and production data. It can therefore be implemented across many countries and over time. A recent literature

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in international trade, including Arkolakis, Costinot, and Rodríguez-Clare (2012), Melitz and Redding (2014), and Feenstra and Weinstein (2010), measures the aggregate welfare gains from trade by first estimating model parameters from a gravity equation (typically, the elasticity of imports with respect to trade costs) and then combining these parameters with aggregate statistics to calculate the impact of trade on aggregate real income. We estimate model parameters from a nonhomothetic gravity equation (the elasticity of imports with respect to both trade costs and income) to calculate the impact of trade on the real income of consumers with different expenditures within the economy.

The premise of our analysis is that consumers at different income levels within an economy may have different expenditure shares in goods from different origins or in different sectors. Studying the distributional implications of trade in this context requires a nonhomothetic demand structure with good-specific Engel curves, where the elasticity of the expenditure share with respect to individuals' total expenditures is allowed to vary across goods. The Almost-Ideal Demand System (AIDS) is a natural choice. As first pointed out by Deaton and Muellbauer (1980a), it is a first-order approximation to any demand system; important for our purposes, it is flexible enough to satisfy the key requirement of good-specific income elasticities and has convenient aggregation properties that allow us to accommodate within-country inequality.

We start with a demand-side result: in the AIDS, the welfare change through the expenditure channel experienced by consumers at each expenditure level as a result of changes in prices, can be recovered from demand parameters and aggregate statistics. These aggregate statistics include the initial levels and changes in aggregate expenditure shares across commodities, and moments from the distribution of expenditure levels across consumers. The intuition for this result is that conditioning on moments of the expenditure distribution, changes in aggregate expenditure shares across goods can be mapped to changes in the relative prices of high- versus low-income elastic goods by inverting the aggregate demand. These relative price changes and demand parameters, in turn, suffice to measure the variation in real income of consumers at each expenditure level through changes in the cost of living.

To study the distributional effects of trade through the expenditure channel, we embed this demand structure into a standard model of international trade, the multisector Armington model. This simple supply side allows us to cleanly highlight the methodological innovation on the demand side.[1] The model allows for cross-country differences in sectoral productivity and bilateral trade costs, and within each sector goods are differentiated by country of origin. We extend this supply-side structure with two features. First, the endowment of the single factor of production varies across consumers, generating within-country inequality. Second, consumer preferences are given by the AIDS, allowing goods from each sector and country of origin to enter with different income elasticity into the demand of individual consumers. As a result, aggregate trade patterns are driven by both standard Ricardian forces (differences in productivities and trade costs across countries and sectors) and demand forces (cross-country differences in income distribution and differences in the income elasticity of exports by sector and country).

In the model, differences between the income elasticities of exported and imported goods shape the gains from trade-cost reductions of poor relative to rich consumers within each country. We show how to use demand-side parameters and changes in aggregate expenditure shares to measure welfare changes experienced by consumers at different income levels in response to foreign shocks. For example, a tilt in the aggregate import basket toward goods consumed mostly by the rich may reveal a fall in the import prices of these goods, and a relative welfare improvement for high-income consumers. In countries where exports are high-income elastic relative to imports, the gains from trade are relatively biased to poorer consumers because opening to trade decreases the relative price of low-income elastic goods. Nonhomotheticity across sectors also shape the unequal gains from trade across consumers because sectors vary in their tradeability (e.g., food versus services) and in the substitutability across goods supplied by different exporters.

1. For example, the model abstracts away from forces that would lead to distributional effects through changes in the earnings distribution, as well as differentiated exporters within sectors, firm heterogeneity, competitive effects, or input-output linkages. Future work could consider embedding the AIDS into models with a richer supply side.

To quantify the unequal gains from trade, we need estimates of the elasticity of individual expenditure shares by sector and country of origin with respect to prices and income. A salient feature of the model is that it delivers a sectoral nonhomothetic gravity equation to estimate these key parameters from readily available data on production and trade flows. The estimation identifies which countries produce high- or low-income elastic goods by projecting budget shares within each sector on standard gravity forces (e.g., distance, border, and common language) and a summary statistic of the importer's income distribution whose elasticity can vary across exporters.[2] Consistent with the existing empirical literature, such as Hallak and Schott (2011) and Feenstra and Romalis (2014), we find that richer countries export goods with higher income elasticities within sectors. The estimation also identifies the sectors whose goods are relatively more valued by rich consumers by projecting sectoral expenditure shares on a summary statistic of the importer's income distribution. Consistent with Hallak (2010), our results also suggest nonhomotheticities across origin countries and across sectors.

Using the estimated parameters, we apply the results from the theory to ask: who are the winners and losers of trade within countries, how large are the distributional effects, and what country characteristics are important to shape these effects? To answer these questions, we perform the counterfactual exercise of increasing trade costs so that each country is brought from its current trade shares to autarky, and compute the gains from trade corresponding to each percentile of the income distribution in each country (i.e., the real income that would be lost by each percentile because of a shut down of trade).

We find a propoor bias of trade in every country. On average, the real income loss from closing off trade is 63% at the 10th percentile of the income distribution and 28% for the 90th percentile. This bias in the gains from trade toward poor consumers hinges on the fact that these consumers spend relatively more on sectors that are more traded, whereas high-income individuals consume relatively more services, which are among the least traded sectors. Additionally, low-income consumers happen to concentrate spending on sectors with a lower elasticity of

2. When nonhomotheticities are shut down, the gravity equation in our model corresponds to the translog gravity equation estimated by Novy (2012) and Feenstra and Weinstein (2010).

substitution across source countries. Larger expenditures in more tradeable sectors and a lower rate of substitution between imports and domestic goods lead to larger gains from trade for the poor than the rich. Although this propoor bias of trade is present in every country, there is heterogeneity in the difference between the gains from trade of poor and rich consumers across countries. In countries with a lower income elasticity of exports, the gains from trade tend to be less favorable for poor consumers because opening to trade causes an increase in the relative price of low-income elastic goods. Similar results appear in counterfactuals involving smaller changes in trade costs than a movement to autarky; for example, a small reduction in the cost of importing in the food or manufacturing sectors also exhibits a propoor bias. However, trade-cost reductions affecting only the service sectors (which are relatively high-income elastic) benefits the rich relatively more.

As mentioned, our approach to measure welfare gains from trade using aggregate statistics is close to a recent literature that studies the aggregate welfare gains from trade summarized by Costinot and Rodríguez-Clare (2014). This literature confronts the challenge that price changes induced by trade costs are not commonly available by inferring them through the model structure from changes in trade shares.[3] These approaches are designed to measure only aggregate gains rather than distributional consequences.[4] In our setting, we exploit properties of a nonhomothetic demand system that also allows us to infer changes in prices from trade shares and to trace out the welfare consequences of these price changes across different consumers within countries. We are motivated by the belief that an approach that is able to quantify the (potentially) unequal gains from trade through the expenditure channel for many countries is useful in assessing the implications of trade, particularly because much of the public opposition toward increased openness stems from the belief that welfare changes are unevenly distributed.

3. For example, autarky prices are rarely observed in data but under standard assumptions on preferences the autarky expenditure shares are generally known. The difference between autarky and observed trade shares can then be used to back out the price changes caused by a counterfactual movement to autarky.

4. Two exceptions are Burstein and Vogel (2012) and Galle, Rodríguez-Clare, and Yi (2014), which use aggregate trade data to estimate the effects of trade on the distribution of earnings.

Of course, we are not the first to allow for differences in income elasticities across goods in an international trade framework. Theoretical contributions to this literature including Markusen (1986), Flam and Helpman (1987), and Matsuyama (2000) develop models where richer countries specialize in high-income elastic goods through supply-side forces, while Fajgelbaum, Grossman, and Helpman (2011) study cross-country patterns of specialization that result from home market effects in vertically differentiated products. Recent papers by Hallak (2006), Fieler (2011), Caron, Fally, and Markusen (2014), and Feenstra and Romalis (2014) find that richer countries export goods with higher income elasticity.[5] This role of nonhomothetic demand and cross-country differences in the income elasticity of exports in explaining trade data is an important motivation for our focus on explaining the unequal gains from trade through the expenditure channel.

These theoretical and empirical studies use a variety of demand structures. To our knowledge, only a few studies have used the AIDS in the international trade literature: Feenstra and Reinsdorf (2000) show how prices and aggregate expenditures relate to the Divisia index in the AIDS and suggest that this demand system could be useful for welfare evaluation in a trade context, Feenstra (2010) works with a symmetric AIDS expenditure function to study the entry of new goods, and Chaudhuri, Goldberg, and Gia (2006) use the AIDS to determine the welfare consequences in India of enforcing the Agreement on Trade-Related Intellectual Property Rights.[6] Neary (2004) and Feenstra, Ma, and Rao (2009) use the AIDS for making aggregate real income comparisons across countries and over time using data from the International Comparison Project. Aguiar and Bils (2015) estimated an AIDS in the United States to measure

5. See also Schott (2004), Khandelwal (2010), and Hallak and Schott (2011) who provide evidence that richer countries export higher-quality goods, which typically have high-income elasticity of demand. In this article we abstract from quality differentiation within sectors, but note that our methodology could be implemented using disaggregated trade data where differences in the income elasticity of demand may be driven by differences in quality.

6. If good-specific income elasticities are neutralized, the AIDS collapses to the homothetic translog demand system studied in an international trade context by Kee, Nicita, and Olarreaga (2008), Feenstra and Weinstein (2010), Arkolakis, Costinot, and Rodríguez-Clare (2010), and Novy (2012).

inequality in total consumption expenditures from consumption patterns.

A few publications study the effect of trade on inequality through the expenditure channel. Porto (2006) studies the effect of price changes implied by a tariff reform on the distribution of welfare using consumer survey data from Argentina, Faber (2013) exploits Mexico's entry into NAFTA to study the effect of input tariff reductions on the price changes of final goods of different quality, and Atkin, Faber, and Gonzalez-Navarro (2015) study the effect of foreign retailers on consumer prices in Mexico. While these papers use detailed microdata for specific countries in the context of major reforms, our approach provides a framework to quantify the unequal gains from trade across consumers over a large set of countries using aggregate trade and production data. Within our framework we are able to show theoretically how changes in trade costs map to the welfare changes of individuals in each point of the expenditure distribution, how to compute these effects using model parameters and aggregate statistics, and how to estimate the parameters from cross-country trade and production data.

There is of course a large literature that examines trade and inequality through the earnings channel. A dominant theme in this literature, as summarized by Goldberg and Pavcnik (2007), has been the poor performance of Stolper-Samuelson effects, which predict that trade increases the relative wages of low-skill workers in countries where these workers are relatively abundant, in rationalizing patterns from low-income countries.[7] We complement these and other studies that focus on the earnings channel by examining the implications of trade through the expenditure channel.

The remainder of the article is divided into five sections. Section II uses standard consumer theory to derive generic expressions for the distribution of welfare changes across consumers and applies these results to the AIDS. Section III embeds these results in a standard trade framework, derives the nonhomothetic gravity equation, and provides the

7. Several studies, such as Feenstra and Hanson (1996), Helpman et al. (2012), Brambilla, Lederman, and Porto (2012), Frias, Kaplan, and Verhoogen (2012), and Burstein, Cravino, and Vogel (2013) study different channels through which trade affects the distribution of earnings such as outsourcing, labor market frictions, quality upgrading, or capital-skill complementarity.

expressions to determine the gains from trade across consumers. Section IV estimates the key elasticities from the gravity equation. Section V presents the results of counterfactuals that simulate foreign-trade cost shocks. Section VI concludes.

II. Consumers

We start by deriving generic expressions for the distribution of welfare changes in response to price changes across consumers that vary in their total expenditures. We only use properties of demand implied by standard demand theory. In Section III, we link these results to a standard model of trade in general equilibrium.

II.A. Definition of the Expenditure Channel

We study an economy with J goods for final consumption with price vector $\mathbf{p} = \{p_j\}_{j=1}^{J}$ taken as given by $h = 1, \ldots, H$ consumers. Consumer h has indirect utility v_h and total expenditures x_h. We denote the indirect utility function by $v(x_h, \mathbf{p})$. We let $s_{j,h} \equiv s_j(x_h, \mathbf{p})$ be the share of good j in the total expenditures of individual h, and $S_j = \sum_h \left(\frac{x_h}{\sum_{h'} x_{h'}}\right) s_{j,h}$ be the share of good j in aggregate expenditures.

Consider the change in the log of indirect utility of consumer h due to infinitesimal changes in log prices $\{\hat{p}_j\}_{j=1}^{J}$ and in the log of the expenditure level $\hat{x}_h$:[8]

$$\hat{v}_h = \sum_{j=1}^{J} \frac{\partial \ln v(x_h, \mathbf{p})}{\partial \ln p_j} \hat{p}_j + \frac{\partial \ln v(x_h, \mathbf{p})}{\partial \ln x_h} \hat{x}_h. \tag{1}$$

The equivalent variation of consumer h associated with $\{\hat{p}_j\}_{j=1}^{J}$ and $\hat{x}_h$ is defined as the change in log expenditures, $\hat{\omega}_h$, that leads to the indirect utility change $\hat{v}_h$ at constant prices:

$$\hat{v}_h = \frac{\partial \ln v(x_h, \mathbf{p})}{\partial \ln x_h} \hat{\omega}_h. \tag{2}$$

8. Throughout the article, we use $\hat{z} \equiv d \ln(z)$ to denote the infinitesimal change in the log of variable z.

Combining equations (1) and (2) and applying Roy's identity gives a well-known formula for the equivalent variation:[9]

$$\hat{\omega}_h = \sum_{j=1}^{J} (-\hat{p}_j) s_{j,h} + \hat{x}_h. \tag{3}$$

The first term on the right-hand side of equation (3) is an expenditure-share weighted average of price changes. It represents what we refer to as the expenditure effect. It is the increase in the cost of living caused by a change in prices applied to the the preshock expenditure basket. Henceforth, we refer to $\hat{\omega}_h$ as the welfare change of individual h, acknowledging that by this we mean the equivalent variation, expressed as share of the initial level of expenditures, associated with a change in prices or in the expenditure level of individual h.

To organize our discussion it is useful to rewrite equation (3) as follows:

$$\hat{\omega}_h = \hat{W} + \hat{\psi}_h + \hat{x}_h, \tag{4}$$

where

$$\hat{W} \equiv \sum_{j=1}^{J} (-\hat{p}_j) S_j \tag{5}$$

is the aggregate expenditure effect, and

$$\hat{\psi}_h \equiv \sum_{j=1}^{J} (-\hat{p}_j)(s_{j,h} - S_j) \tag{6}$$

is the individual expenditure effect of consumer h.

The term $\hat{W}$ is the welfare change through the expenditure channel that corresponds to every consumer either in the absence of within-country inequality or under homothetic preferences. It also corresponds to the welfare change through the cost of expenditures for a hypothetical representative consumer. In turn, the term $\hat{\psi}_h$ captures that consumers may be differentially affected by the same price changes due to differences in the composition of their expenditure basket. It is different from zero for some consumers only if there is variation across consumers in how they allocate expenditure shares across goods. The focus of

9. See Theil (1975).

this article is to study how international trade impacts the distribution $\{\hat{\psi}_h\}_{h=1}^{H}$.

II.B. Almost-Ideal Demand System

The Almost-Ideal Demand System (AIDS) introduced by Deaton and Muellbauer (1980a) belongs to the family of log price-independent generalized preferences defined by Muellbauer (1975). The latter are defined by the indirect utility function

$$v(x_h, \mathbf{p}) = F\left[\left(\frac{x_h}{a(\mathbf{p})}\right)^{\frac{1}{b(\mathbf{p})}}\right], \tag{7}$$

where $a(\mathbf{p})$ and $b(\mathbf{p})$ are price aggregators and $F[\cdot]$ is a well-behaved increasing function. The AIDS is the special case that satisfies

$$a(\mathbf{p}) = \exp\left(\underline{\alpha} + \sum_{j=1}^{J} \alpha_j \ln p_j + \frac{1}{2}\sum_{j=1}^{J}\sum_{k=1}^{J} \gamma_{jk} \ln p_j \ln p_k\right), \tag{8}$$

$$b(\mathbf{p}) = \exp\left(\sum_{j=1}^{J} \beta_j \ln p_j\right), \tag{9}$$

where the parameters satisfy the restrictions $\sum_{j=1}^{J} \alpha_j = 1$, $\sum_{j=1}^{J} \beta_j = \sum_{j=1}^{J} \gamma_{jk} = 0$, and $\gamma_{jk} = \gamma_{kj}$ for all j, k.[10]

The first price aggregator, $a(\mathbf{p})$, has the form of a homothetic translog price index. It is independent from nonhomotheticities and can be interpreted as the cost of a subsistence basket of goods. The second price aggregator, $b(\mathbf{p})$, captures the relative price of high-income elastic goods. For our purposes, a key feature of these preferences is that the larger is the consumer's expenditure level x_h relative to $a(\mathbf{p})$, the larger is the welfare gain from a reduction in the cost of high-income elastic goods, as captured by a reduction in $b(\mathbf{p})$. We refer to a and b as the homothetic and nonhomothetic components of preferences, respectively.

10. These parameter restrictions correspond to the adding up, homogeneity, and symmetry constraints implied by individual rationality, and ensure that the AIDS is a well-defined demand system. No direct utility representation of the AIDS exists, but this poses no restriction for our purposes. See Deaton and Muellbauer (1980b).

Applying Shephard's lemma to the indirect utility function defined by equations (7) to (9) generates an expenditure share in good j for individual h equal to:

$$s_j(\mathbf{p}, x_h) = \alpha_j + \sum_{k=1}^{J} \gamma_{jk} \ln p_k + \beta_j \ln\left(\frac{x_h}{a(\mathbf{p})}\right) \tag{10}$$

for $j = 1, \ldots, J$. We assume that equation (10) predicts nonnegative expenditure shares for all goods and consumers, so that the nonnegativity restriction is not binding. Since expenditure shares add up to 1, this guarantees that expenditure shares are also smaller than 1. We discuss how to incorporate this restriction in the empirical analysis in Section IV.

These expenditure shares have two features that suit our purposes. First, the elasticity with respect to the expenditure level is allowed to be good-specific.[11] Goods for which $\beta_j > 0$ have positive income elasticity, while goods for which $\beta_j < 0$ have negative income elasticity.[12] Second, they admit aggregation: market-level behavior can be represented by the behavior of a representative consumer. The aggregate market share of good j is $S_j = s_j(\mathbf{p}, \tilde{x})$, where $\tilde{x}$ is an inequality-adjusted mean of the distribution of expenditures across consumers, $\tilde{x} = \bar{x}e^{\Sigma}$, where $\bar{x} \equiv \mathbb{E}[x_h]$ is the mean and $\Sigma \equiv \mathbb{E}\left[\frac{x_h}{\bar{x}} \ln\left(\frac{x_h}{\bar{x}}\right)\right]$ is the Theil index of the expenditure distribution.[13] We can write the aggregate shares as

$$S_j = \alpha_j + \sum_{k=1}^{J} \gamma_{jk} \ln p_k + \beta_j y, \tag{11}$$

11. We note that the AIDS restricts these elasticities to be constant, thus ruling out the possibility that demand peaks at intermediate levels of income. Several discrete-choice models of trade with vertically differentiated products—such Flam and Helpman (1987), Matsuyama (2000), or the multiquality extension in Section VII of Fajgelbaum, Grossman, and Helpman (2011)—feature nonmonotonic income elasticities. Banks, Blundell, and Lewbel (1997) and Lewbel and Pendakur (2009) develop extensions of the AIDS that allow for nonconstant income elasticities.

12. Note that γ's and β's are semi-elasticities since they relate expenditure shares to logs of prices and income, but we refer to them as elasticities to save notation. Note also that although we define x_h as the individual expenditure level, we follow standard terminology and refer to β_j as the income elasticity of the expenditure share in good j.

13. The Theil index is a measure of inequality that takes the minimum $\Sigma = 0$ if the distribution is concentrated at a single point. In the case of a log-normal expenditure distribution with variance σ^2, it is $\Sigma = \frac{1}{2}\sigma^2$.

where $y = \ln\left(\frac{\tilde{x}}{a(\mathbf{p})}\right)$. Henceforth, we follow Deaton and Muellbauer (1980a) and refer to y as the adjusted "real" income.

II.C. The Individual Expenditure Effect with Almost-Ideal Demand

From equations (10) and (11), the difference in the budget shares of good j between a consumer with expenditure level x_h and the representative consumer is

$$s_{j,h} - S_j = \beta_j \ln\left(\frac{x_h}{\tilde{x}}\right). \tag{12}$$

Consumers who are richer than the representative consumer have larger expenditure shares than the representative consumer in positive β_j goods and lower shares in negative β_j goods. Combining equation (12) with the individual expenditure effect defined in equation (6), we obtain

$$\hat{\psi}_h = -\underbrace{\left(\sum_{j=1}^{J} \beta_j \hat{p}_j\right)}_{=\hat{b}} \times \ln\left(\frac{x_h}{\tilde{x}}\right), \tag{13}$$

where $\hat{b}$ is the change in the log of the nonhomothetic component $b(\mathbf{p})$. Note that $\frac{\hat{b}}{J}$ equals the covariance between the good-specific income elasticities and the price changes.[14] A positive (negative) value of $\hat{b}$ reflects an increase in the relative prices of high- (low-) income elastic goods, leading to a relative welfare loss for rich (poor) consumers.

Collecting terms, the welfare change of consumer h is

$$\hat{\omega}_h = \hat{W} - \hat{b} \times \ln\left(\frac{x_h}{\tilde{x}}\right) + \hat{x}_h. \tag{14}$$

Given a distribution of expenditure levels x_h across consumers, this expression generates the distribution of welfare changes in the economy through the expenditure channel.

A useful property of this structure is that the terms $\{\hat{W}, \hat{b}\}$ can be expressed as a function of demand parameters and aggregate statistics. Intuitively, these terms are simply weighted

14. That is, $\mathbb{COV}(\{\beta_j\}, \hat{p}_j) \equiv \frac{1}{J}\sum_j(\beta_j - \frac{1}{J}\sum_{j'}\beta_{j'})(p_j - \frac{1}{J}\sum_{j'}p_{j'}) = \sum_{j=1}^{J}\hat{p}_j\beta_j$, where the last equality follows from the fact that the elasticities $\{\beta_j\}$ add up to 0.

averages of price changes, which can be expressed as a function of changes in aggregate expenditure shares and in the change in adjusted real income y after inverting the aggregate demand system in equation (11).

Let $\{\mathbf{S}, \hat{\mathbf{S}}\}$ be vectors with the levels and changes in aggregate expenditure shares, S_j and $\hat{S}_j$. We also collect the parameters α_j and β_j in the vectors $\{\boldsymbol{\alpha}, \boldsymbol{\beta}\}$ and define $\boldsymbol{\Gamma}$ as the matrix with element γ_{jk} in row j, column k. With this notation, the demand system is characterized by the parameters $\{\underline{\alpha}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\Gamma}\}$. We choose an arbitrary good n as the numeraire and assume that expenditure levels are expressed in units of this good. Excluding good n from the demand system, the aggregate expenditure shares in equation (11) are represented by

$$\mathbf{S_{-n}} = \boldsymbol{\alpha}_{-\boldsymbol{n}} + \boldsymbol{\Gamma}_{-\boldsymbol{n}} \ln \mathbf{p_{-n}} + \boldsymbol{\beta}_{-\boldsymbol{n}} y, \tag{15}$$

where $\mathbf{S_{-n}}$ is a vector with all expenditure shares but the numeraire and $\boldsymbol{\Gamma}_{-\boldsymbol{n}}$ denotes that the nth row and the nth column are excluded from $\boldsymbol{\Gamma}$. We write the change in aggregate expenditure shares from equation (15) as $\mathbf{dS_{-n}} = \boldsymbol{\Gamma}_{-\boldsymbol{n}} \hat{\mathbf{p}}_{\mathbf{-n}} + \boldsymbol{\beta}_{-\boldsymbol{n}} dy$ and express the vector of relative price changes as

$$\hat{\mathbf{p}}_{\mathbf{-n}} = \boldsymbol{\Gamma}_{-\boldsymbol{n}}^{-\mathbf{1}} (\mathbf{dS_{-n}} - \boldsymbol{\beta}_{-\boldsymbol{n}} dy). \tag{16}$$

Combining with the definition of the aggregate and the individual expenditure effects from equations (5) and (6) yields

$$\hat{W} = -\mathbf{S}'_{\mathbf{-n}} \boldsymbol{\Gamma}_{-\boldsymbol{n}}^{-\mathbf{1}} (\mathbf{dS_{-n}} - \boldsymbol{\beta}_{-\boldsymbol{n}} dy), \tag{17}$$

$$\hat{b} = -\boldsymbol{\beta}'_{-\boldsymbol{n}} \boldsymbol{\Gamma}_{-\boldsymbol{n}}^{-\mathbf{1}} (\mathbf{dS_{-n}} - \boldsymbol{\beta}_{-\boldsymbol{n}} dy). \tag{18}$$

These expressions show $\hat{W}$ and $\hat{b}$ as functions of levels and changes in aggregate shares, the substitution parameters γ_{jk}, the income elasticity parameters β_j, and the change in adjusted real income, dy. In addition, using $dy = \hat{\tilde{x}} - \hat{a}$ and Shephard's lemma allows us to express dy as follows:[15]

$$dy = \frac{\hat{\tilde{x}} - [\mathbf{S}'_{\mathbf{-n}} - y\boldsymbol{\beta}'_{-\boldsymbol{n}}] \boldsymbol{\Gamma}_{-\boldsymbol{n}}^{-\mathbf{1}} \mathbf{dS_{-n}}}{1 - [\mathbf{S}'_{\mathbf{-n}} - y\boldsymbol{\beta}'_{-\boldsymbol{n}}] \boldsymbol{\Gamma}_{-\boldsymbol{n}}^{-\mathbf{1}} \boldsymbol{\beta}_{-\boldsymbol{n}}}. \tag{19}$$

15. To derive equation (19), we use that $\hat{a} \equiv \frac{\partial \ln a}{\partial \ln \mathbf{p}'_{\mathbf{-n}}} \hat{\mathbf{p}}_{\mathbf{-n}} = [\mathbf{S}'_{\mathbf{-n}} - \mathbf{y}\boldsymbol{\beta}'_{-\boldsymbol{n}}] \hat{\mathbf{p}}_{\mathbf{-n}}$, where the second line follows from Shephard's lemma. Replacing $\hat{\mathbf{p}}_{\mathbf{-n}}$ from equation (16) into this expression, using $dy = \hat{\tilde{x}} - \hat{a}$, and solving for dy yields equation (19).

Equations (17) to (19) allow us to express the aggregate and individual expenditure effects as function of the level and changes in aggregate expenditure shares, the parameters $\{\beta_j\}, \{\gamma_{jk}\}$, the initial level of adjusted real income, y, and the change in income of the representative consumer, $\hat{\bar{x}}$. These formulas correspond to infinitesimal welfare changes and can be used to compute a first-order approximation to the exact welfare change corresponding to a discrete set of price changes.[16]

In deriving this result, we have not specified the supply side of the economy, and we have allowed for arbitrary changes in the distribution of individual expenditure levels, $\{\hat{x}_h\}$. These demand-side expressions can be embedded in different supply-side structures to study the welfare changes associated with specific counterfactuals. In the next section, we embed them in a model of international trade to compute the welfare effects caused by changes in trade costs as function of observed expenditure shares.

III. International Trade Framework

We embed the results from the previous section in an Armington trade model. Section III.A develops a multisector Armington model with almost-ideal preferences and within-country income heterogeneity. Section III.B derives the nonhomothetic gravity equation implied by the framework. Section III.C presents expressions for the welfare changes across households resulting from foreign shocks.

III.A. Multisector Model

The world economy consists of N countries, indexed by n as importer and i as exporter. Each country specializes in the production of a different variety within each sector $s = 1, ..., S$, so that there are $J = N \times S$ varieties, each defined by a sector-origin dyad. These varieties are demanded at different income elasticities. For example, expenditure shares on textiles from India may decrease with individual income, while shares on U.S. textiles may increase with income. We let p^s_{ni} be the price

16. In assuming that the changes in prices are small, we have not allowed for the possibility that consumers drop varieties in response to the price changes. When we measure the welfare losses from moving to autarky in the international trade setup, we account for this possibility.

in country n of the goods in sector s imported from country i, and $\mathbf{p}_n$ be the price vector in country n. The iceberg trade cost of exporting from i to n in sector s is τ^s_{ni}. Perfect competition implies that $p^s_{ni} = \tau^s_{ni} p^s_{ii}$.

Labor is the only factor of production. Country n has constant labor productivity Z^s_n in sector s. Assuming that every country has positive production in every sector, the wage per effective unit of labor in country n is $w_n = p^s_{nn} Z^s_n$ for all $s = 1, ..., S$, and an individual h in country i with z_h effective units of labor receives income of $x_h = z_h \times w_n$. Each country is characterized by a mean $\bar{z}_n$ and a Theil index Σ_n of its distribution of effective units of labor across the workforce. Therefore, the income distribution has mean $\bar{x}_n = w_n \bar{z}_n$ and Theil index Σ_i. Income equals expenditure at the individual level (we use these terms interchangeably) and at the aggregate level due to balanced trade.

We assume almost-ideal demand and reformulate the aggregate expenditure share equation (11) in this context. Let X^s_{ni} be the value of exports from exporter i to importer n in sector s, and let Y_n be the total income of the importer. The share of aggregate expenditures in country n devoted to goods from country i in sector s is

$$S^s_{ni} = \frac{X^s_{ni}}{Y_n} = \alpha^s_{ni} + \sum_{s'=1}^{S} \sum_{i'=1}^{N} \gamma^{ss'}_{ii'} \ln p^{s'}_{ni'} + \beta^s_i y_n, \tag{20}$$

where $a_n = a(\mathbf{p}_n)$ is the homothetic component of the price index (equation (8)) in country n and $y_n = \ln\left(\frac{\bar{x}_n}{a_n}\right) + \Sigma_n$ is the adjusted real income of the economy. The income elasticity β^s_i is allowed to vary across both sectors and exporters. The richer the importing country (higher $\bar{x}_n$) or the more unequal it is (higher Σ_n), the larger its expenditure share in varieties with positive income elasticity, $\beta^s_i > 0$. In turn, the parameter α^s_{in} may vary across exporters, sectors, and importers, and it captures the overall taste in country n for the goods exported by country i in sector s independently from prices or income in the importer. These coefficients must satisfy $\sum_{i=1}^{N} \sum_{s=1}^{S} \beta^s_i = 0$ and $\sum_{i=1}^{N} \sum_{s=1}^{S} \alpha^s_{ni} = 1$ for all $n = 1, \ldots, N$.

The coefficient $\gamma^{ss'}_{ii'}$ is the semi-elasticity of the expenditure share in good (i, s) with respect to the price of good (i', s'). We assume no cross-substitution between goods in different sectors

($\gamma_{ii'}^{ss'} = 0$ if $i \neq i'$) and, within each sector s, we assume the same elasticity between goods from different sources ($\gamma_{ii'}^{ss}$ is the same for all $i' \neq i$ for each s, but allowed to vary across s). Formally,

$$\gamma_{ii'}^{ss'} = \begin{cases} -\left(1-\frac{1}{N}\right)\gamma^s & \text{if } s = s' \text{ and } i = i', \\ \frac{\gamma^s}{N} & \text{if } s = s' \text{ and } i \neq i', \\ 0 & \text{if } s \neq s'. \end{cases} \tag{21}$$

This structure on the elasticities is convenient because it simplifies the algebra, but it is not necessary to reach analytic results.[17] It allows us to cast a demand system that looks similar to a two-tier demand system (across sectors in the upper tier and across origins within each sector in the lower tier) and to relate it to homothetic multisector gravity models.[18]

Using equation (21), the expenditure share in goods from origin country i in sector s can be simplified to

$$S_{ni}^s = \alpha_{ni}^s - \gamma^s\left[\ln\left(p_{ni}^s\right) - \frac{1}{N}\sum_{i'=1}^{N}\ln p_{ni'}^s\right] + \beta_i^s y_n. \tag{22}$$

The corresponding expenditure share for consumer h in goods from country n in sector s is

$$s_{ni,h}^s = \alpha_{ni}^s - \gamma^s\left[\ln\left(p_{ni}^s\right) - \frac{1}{N}\sum_{i'=1}^{N}\ln p_{ni'}^s\right] + \beta_i^s\left(\ln\left(\frac{x_h}{\tilde{x}_n}\right) + y_n\right). \tag{23}$$

Adding up equation (22) across exporters, the share of sector s in the total expenditures of country n is:

$$S_n^s = \sum_{i=1}^{N} S_{ni}^s = \overline{\alpha}_n^s + \overline{\beta}^s y_n, \tag{24}$$

17. The normalization by N in equation (21) only serves the purpose of easing the notation in following derivations.

18. This nesting is a standard approach to the demand structure in multisector trade models. For example, see Feenstra and Romalis (2014) or Costinot and Rodríguez-Clare (2014). Imposing symmetry within sectors also allows us to compare results to estimates of gravity equations derived under a translog demand system from the literature (see later discussion).

where

$$\overline{\alpha}_n^s = \sum_{i=1}^{N} \alpha_{ni}^s,$$

$$\overline{\beta}^s = \sum_{i=1}^{N} \beta_i^s.$$

In turn, the share of sector s in total expenditures of consumer h is

$$s_{n,h}^s = \sum_{i=1}^{N} s_{ni,h}^s = \overline{\alpha}_n^s + \overline{\beta}^s \left(y_n + \ln\left(\frac{x_h}{\tilde{x}_n} \right) \right). \tag{25}$$

Equations (24) and (25) show that the expenditure shares across sectors have an "extended Cobb-Douglas" form, which allows for nonhomotheticicities across sectors through $\overline{\beta}^s$ on top of the fixed expenditure share $\overline{\alpha}_n^s$. We refer to $\overline{\beta}^s$ in equation (24) as the "sectoral betas."[19]

III.B. Nonhomothetic Gravity Equation

The model yields a sectoral nonhomothetic gravity equation that depends on aggregate data and the demand parameters. These parameters are the elasticity of substitution γ^s across exporters in sector s and the income elasticity of the goods supplied by each exporter in each sector, $\{\beta_n^s\}$. Combining equation (22) and the definition of y_n gives

$$\frac{X_{ni}^s}{Y_n} = \alpha_{ni}^s - \gamma^s \ln\left(\frac{\tau_{ni}^s p_{ii}^s}{\overline{\tau}_n^s \overline{p}^s} \right) + \beta_i^s \left[\ln\left(\frac{\overline{x}_n}{a(\mathbf{p}_n)} \right) + \Sigma_n \right], \tag{26}$$

where

$$\overline{\tau}_n^s = \exp\left(\frac{1}{N} \sum_{i=1}^{N} \ln\left(\tau_{ni}^s\right) \right)$$

19. If $\overline{\beta}^s = 0$ for all s (so that nonhomotheticicities across sectors are shut down), sectoral shares by importer are constant at $S_n^s = \overline{\alpha}_n^s$, as it would be the case with Cobb-Douglas demand across sectors.

and

$$\overline{p}^s = \exp\left(\frac{1}{N}\sum_{i=1}^{N} \ln\left(p_{ii}^s\right)\right).$$

Income of each exporter i in sector s equals the sum of sales to every country, $Y_i^s = \sum_{n=1}^{N} X_{ni}^s$. Using this condition and equation (26), we can solve for $\gamma^s \ln\left(\frac{p_{ii}^s}{\overline{p}^s}\right)$. Replacing this term back into equation (26), import shares in country n can be expressed in the gravity form:

$$\frac{X_{ni}^s}{Y_n} = A_{ni}^s + \frac{Y_i^s}{Y_W} - \gamma^s T_{ni}^s + \beta_i^s \Omega_n, \quad (27)$$

where $Y_W = \sum_{i=1}^{I} Y_i$ stands for world income, and where

$$A_{ni}^s = \alpha_{ni}^s - \sum_{n'=1}^{N}\left(\frac{Y_{n'}}{Y_W}\right)\alpha_{n'i}^s, \quad (28)$$

$$T_{ni}^s = \ln\left(\frac{\tau_{ni}^s}{\overline{\tau}_n^s}\right) - \sum_{n'=1}^{N}\left(\frac{Y_{n'}}{Y_W}\right)\ln\left(\frac{\tau_{n'i}^s}{\overline{\tau}_{n'}^s}\right), \quad (29)$$

$$\Omega_n = \left[\ln\left(\frac{\overline{x}_n}{a_n}\right) + \Sigma_n\right] - \sum_{n'=1}^{N}\left(\frac{Y_{n'}}{Y_W}\right)\left[\ln\left(\frac{\overline{x}_{n'}}{a_{n'}}\right) + \Sigma_{n'}\right]. \quad (30)$$

The first term in equation (27), A_{ni}^s, captures cross-country differences in tastes across sectors or exporters; this term vanishes if α_{ni}^s is constant across importers n. The second term, $\frac{Y_i^s}{Y_W}$, captures relative size of the exporter because of, for example, high productivity relative to other countries. The third term, T_{ni}^s, measures both bilateral trade costs and multilateral resistance (i.e., the cost of exporting to third countries).

The last term in equation (27), $\beta_i^s \Omega_n$, is the nonhomothetic component of the gravity equation. It includes the good-specific Engel curves needed to measure the unequal gains from trade across consumers. This term captures the “mismatch” between the income elasticity of the exporter and the income distribution of the importer. The larger Ω_n is, because either average income or inequality in the importing country n are high relative to the rest of the world, the higher the share of expenditures devoted to goods in sector s from country i when i sells high income-elastic goods ($\beta_i^s > 0$). If nonhomotheticities are shut down, this last terms disappears and the gravity equation in (27) becomes the translog gravity equation.

III.C. Distributional Impact of a Foreign-Trade Shock

Using the results from Section III, we derive the welfare impacts of a foreign-trade shock across the expenditure distribution. Without loss of generality we normalize the wage in country n to 1, $w_n = 1$. Consider a foreign shock to this country consisting of an infinitesimal change in foreign productivities, foreign endowments, or trade costs between any country pair. From the perspective of an individual consumer h in country n, this shock affects welfare through the price changes $\{\hat{p}_{ni}^s\}_{i,s}$ and the income change $\hat{x}_h$. From equations (21) and (22), the change in the price of imported relative to own varieties satisfies:

$$\hat{p}_{ni}^s - \hat{p}_{nn}^s = -\frac{dS_{ni}^s - dS_{nn}^s}{\gamma^s} + \frac{1}{\gamma^s}\left(\beta_i^s - \beta_n^s\right)dy_n. \tag{31}$$

Because only foreign shocks are present, the change in income $\hat{x}_h$ is the same for all consumers and equal to the change in the price of domestic commodities, $\hat{x}_h = \hat{\bar{x}} = \hat{p}_{nn}^s = 0$ for all h in country N and for all $s = 1, ..., S$.[20] Imposing these restrictions, we can rewrite equation (17) as

$$\hat{W}_n \equiv \hat{W}_{H,n} + \hat{W}_{NH,n}, \tag{32}$$

where

$$\hat{W}_{H,n} = \sum_{s=1}^{S}\sum_{i=1}^{N}\frac{1}{\gamma^s}S_{ni}^s\left(dS_{ni}^s - dS_{nn}^s\right), \tag{33}$$

$$\hat{W}_{NH,n} = \sum_{s=1}^{S}\sum_{i=1}^{N}\frac{1}{\gamma^s}S_{ni}^s\left(\beta_n^s - \beta_i^s\right)dy_n. \tag{34}$$

Using these restrictions, we can also rewrite the slope of the individual effect in equation (18) as

$$\hat{b}_n = \sum_{s=1}^{S}\sum_{i=1}^{N}\frac{\beta_i^s}{\gamma^s}\left(dS_{nn}^s - dS_{ni}^s + \left(\beta_i^s - \beta_n^s\right)dy_n\right), \tag{35}$$

20. Note that because of the Ricardian supply-side specification, there is no change in the relative price across domestic goods or in relative incomes across consumers.

and the change in the adjusted real income from equation (19) as

$$dy_n = \frac{\sum_{s=1}^{S}\sum_{i=1}^{N}\frac{1}{\gamma^s}\left(S^s_{ni} - \beta^s_{ni}y_n\right)\left(dS^s_{ni} - dS^s_{nn}\right)}{1 - \sum_{s=1}^{S}\sum_{i=1}^{N}\frac{1}{\gamma^s}\left(S^s_{ni} - \beta^s_i y_n\right)\left(\beta^s_n - \beta^s_i\right)}. \quad (36)$$

Expressions (32) to (36) provide a closed-form characterization of the welfare effects of a foreign-trade shock that includes three novel margins. First, preferences are nonhomothetic with good-specific income elasticities. Second, the formulas accommodate within-country inequality through the Theil index of expenditure distribution Σ_n, which enters through the level of y_n. Third, and key for our purposes, the expressions characterize the welfare change experienced by individuals at each income level, so that the entire distribution of welfare changes across consumers h in country n can be computed from equation (14) using:

$$\hat{\omega}_h = \hat{W}_n - \hat{b}_n \times \ln\left(\frac{x_h}{\tilde{x}}\right). \quad (37)$$

The aggregate expenditure effect, $\hat{W}_n$, includes a homothetic part $\hat{W}_{H,n}$ independent from the β^s_n's. When nonhomotheticicities are shut down, this term corresponds to the aggregate gains under translog demand.[21] The aggregate effect also includes and a nonhomothetic part, $\hat{W}_{NH,n}$, which adjusts for the country's pattern of specialization in high- or low-income elastic goods and for the change in adjusted real income.

The key term for measuring unequal welfare effects is the change in the nonhomothetic component $\hat{b}_n$. As we have established, $\hat{b}_n < 0$ implies a decrease in the relative price of high income-elastic goods, which favors high-income consumers. To develop an intuition for how observed trade shares and parameters map to $\hat{b}_n$, consider the single-sector version of the model.

21. Feenstra and Weinstein (2010) measures the aggregate gains from trade in the United States under translog preferences in a context with competitive effects, and Arkolakis, Costinot, and Rodríguez-Clare (2010) study the aggregate gains from trade with competitive effects under homothetic translog demand and Pareto distribution of productivity. The AIDS nests the demand systems in these papers, but we abstract from competitive effects. With a single sector, the translog term in equation (33) becomes $\hat{W}_{H,n} = \sum_{i=1}^{N}\frac{1}{\gamma}S_{ni}(dS_{ni} - dS_{nn})$. Under CES preferences with elasticity σ, the equivalent term is $\frac{1}{1-\sigma}\hat{S}_{nn}$, which depends on just the own trade share. See Arkolakis, Costinot, and Rodríguez-Clare (2012).

Setting $S = 1$ and omitting the s superscript from every variable, equation (35) can be written as

$$\hat{b}_n = \frac{1}{\gamma}\left(\sigma_\beta^2 dy_n - d\overline{\beta}_n\right), \tag{38}$$

where $\sigma_\beta^2 = \sum_{i=1}^N \beta_i^2$, and where

$$\overline{\beta}_n = \sum_{i=1}^N \beta_i S_{ni}. \tag{39}$$

The parameter σ_β^2 is proportional to the variance of the β_n's and captures the strength of nonhomotheticities across goods from different origins. The term $\overline{\beta}_n$ is proportional to the covariance between the S_{ni}'s and the β_i's, and measures the bias in the composition of aggregate expenditure shares of country i toward goods from high-β exporters. The larger is $\overline{\beta}_n$, the relatively more economy n spends in goods that are preferred by high-income consumers. Suppose that $d\overline{\beta}_n > 0$, that is, a movement of aggregate trade shares toward high-β_i exporters; if $\gamma > 0$ and the aggregate real income of the economy stays constant ($dy_n = 0$), this implies a reduction in the relative price of imports from high-β_i exporters, and a positive welfare impact on consumers who are richer than the representative consumer.[22]

Equations (32) to (36) express changes in individual welfare as the equivalent variation of a consumer that corresponds to an infinitesimal change in prices caused by foreign shocks. To obtain the exact change in real income experienced by an individual with expenditure level x_h in country n between an initial scenario under trade (*tr*) and a counterfactual scenario (*cf*) we integrate equation (37),[23]

$$\omega_{n,h}^{tr \to cf} = \left(\frac{W_n^{cf}}{W_n^{tr}}\right)\left(\frac{x_h}{\tilde{x}_n}\right)^{-\ln\left(\frac{b_n^{cf}}{b_n^{tr}}\right)}, \tag{40}$$

where $\frac{W_n^{cf}}{W_n^{tr}}$ and $\frac{b_n^{cf}}{b_n^{tr}}$ correspond to integrating equations (32) to (36) between the expenditure shares in the initial and counterfactual

22. At the same time, keeping prices constant, $dy_n > 0$ would imply a movement of aggregate shares to high-β_i exporters ($d\overline{\beta}_n > 0$). Therefore, conditioning on $d\overline{\beta}_n$, a larger dy_n implies an increase in the relative price of high-income elastic goods.

23. An expression similar to equation (40) appears in Feenstra, Ma, and Rao (2009).

scenarios. If $\omega_{n,h}^{tr\to cf} < 1$, individual h is willing to pay a fraction $1 - \omega_{n,h}^{tr\to cf}$ of her income in the initial trade scenario to avoid the movement to the counterfactual scenario.

In Section V we perform the counterfactual experiment of bringing each country to autarky and simulate partial changes in the trade costs. In each case, we compute equation (40) using the changes in expenditure shares that take place between the observed and counterfactual scenarios. For that, we need the income elasticities $\{\beta_n^s\}$ and the substitution parameters $\{\gamma^s\}$. The next section explains the estimation of the gravity equation to obtain these parameters.

IV. Estimation of the Gravity Equation

In this section, we estimate the nonhomothetic gravity derived in Section III.[24] Section IV.A describes the data, and Section IV.B presents the estimation results.

IV.A. Data

To estimate the nonhomothetic gravity equation we use data compiled by World Input-Output Database (WIOD). The database records bilateral trade flows and production data by sector for 40 countries (27 European countries and 13 other large countries) across 35 sectors that cover food, manufacturing, and services (we take an average of flows between 2005–2007 to smooth out annual shocks). The data record total expenditures by sector and country of origin, as well as final consumption; we use total expenditures as the baseline and report robustness checks that restrict attention to final consumption. We obtain bilateral distance, common language, and border information from CEPII's *Gravity* database. Price levels, adjusted for cross-country quality variation, are obtained from Feenstra and Romalis (2014). Income per capita and population are from the Penn World Tables, and we obtain Gini coefficients from the World Income

24. In principle, one could obtain the parameters from other data sources, such as household surveys, that record consumption variation across households within countries. We have chosen to use cross-country data because it is internally consistent within our framework, and it is a common approach taken in the literature. In Section V.D, we explore results that use parameters estimated from the U.S. consumption expenditure microdata.

Inequality Database (version 2.0c, 2008) published by the World Institute for Development Research.[25]

The left-hand side of equation (27), $\frac{X_{ni}^s}{Y_i}$, can be directly measured using the data from sector s and exporter i's share in country n's expenditures. Similarly, we use country i's sales in sector s to construct $\frac{Y_i^s}{Y_W}$.

The term T_{ni}^s in equation (27) captures bilateral trade costs between exporter i and importer n in sector s relative to the world. Direct measures of bilateral trade costs across countries are unavailable, so we proxy them with bilateral observables. Specifically we assume $\tau_{ni}^s = d_{ni}^{\rho^s} \Pi_j g_{j,ni}^{-\delta_j^s} \tilde{\epsilon}_{ni}^s$, where d_{ni} stands for distance, ρ^s reflects the elasticity between distance and trade costs in sector s, the g's are other gravity variables (common border and common language),[26] and $\tilde{\epsilon}_{ni}^s$ is an unobserved component of the trade cost between i and n in sector s.[27] This allows us to rewrite the gravity equation as

$$\frac{X_{ni}^s}{Y_n} = A_{ni}^s + \frac{Y_i^s}{Y_W} - (\gamma^s \rho^s) D_{ni} + \sum_j \left(\gamma^s \delta_j^s\right) G_{j,ni} + \beta_i^s \Omega_n + \epsilon_{ni}^s, \tag{41}$$

where, letting $\overline{d}_n = \frac{1}{N} \sum_{i=1}^{N} \ln(d_{ni})$,

$$D_{ni} = \ln\left(\frac{d_{ni}}{\overline{d}_n}\right) - \sum_{n'=1}^{N} \left(\frac{Y_{n'}}{Y_W}\right) \ln\left(\frac{d_{n'i}}{\overline{d}_{n'}}\right). \tag{42}$$

and where $G_{j,ni}$ is defined in the same way as equation (42) but with $g_{j,ni}$ instead of d_{ni}.[28] As seen from equation (45), because we do not directly observe trade costs we cannot separately

25. The World Income Inequality Database provides Gini coefficients from both expenditure and income data. Ideally, we would use Ginis from only the expenditure data, but this is not always available for some countries during certain time periods. We construct a country's average Gini using the available data between 2001–2006.

26. Since bilateral distance is measured between the largest cities in each country using population as weights, it is defined when $i = n$; see Mayer and Zignago (2011). Note that we parameterize trade costs such that a positive effect of common language and common border on trade is reflected in $\delta_j^s > 0$.

27. Waugh (2010) includes exporter effects in the trade-cost specification. The gravity equation (27) would be unchanged in this case because the exporter effect would wash out from T_{ni}^s in equation (29).

28. From the structure of trade costs it follows that the error term is $\epsilon_{ni}^s = -\gamma^s \left(\ln\left(\frac{\tilde{\epsilon}_{ni}^s}{\overline{\tilde{\epsilon}_n^s}}\right) - \sum_{n'=1}^N \left(\frac{Y_{n'}}{Y_W}\right) \ln\left(\frac{\tilde{\epsilon}_{n'i}^s}{\overline{\tilde{\epsilon}_{n'}^s}}\right)\right)$ where $\overline{\tilde{\epsilon}_n^s} = \exp\left(\frac{1}{N}\sum_{n'=1}^N \ln\left(\tilde{\epsilon}_{n'i}^s\right)\right)$.

identify γ^s and ρ^s. Following Novy (2012) we set $\rho^s = \rho = 0.177$ for all s.[29]

The term Ω_n in equation (41) captures importer n's inequality-adjusted real income relative to the world. To construct this variable, we assume that the distribution of efficiency units in each country n is log-normal, $\ln z_h \sim \mathcal{N}(\mu_n, \sigma_n^2)$. This implies a log-normal distribution of expenditures with Theil index equal to $\frac{\sigma_n^2}{2}$ where $\sigma_n^2 = 2\left[\Phi^{-1}\left(\frac{gini_n+1}{2}\right)\right]^2$. We construct $\overline{x}_n$ from total expenditure and total population of country n. We follow Deaton and Muellbauer (1980a), and more recently Atkin (2013), to proxy the homothetic component a_n with a Stone index, for which we use $a_n = \sum_i S_{ni} \ln(p_{nn} d_{ni}^{\rho})$, where p_{nn} are the quality-adjusted prices estimated by Feenstra and Romalis (2014). The obvious advantage of this approach is that it avoids the estimation of the α_{ni}^s, which enter the gravity specification nonlinearly and are not required for our welfare calculations. The measure of real spending per capita divided by the Stone price index, $\frac{\overline{x}_i}{a_i}$, is strongly correlated with countries' real income per capita; this suggests that Ω_i indeed captures the relative difference in real income across countries.

To measure A_{ni}^s, we decompose α_{ni}^s into an exporter effect α_i, a sector-specific effect α^s, and an importer-specific taste for each sector ε_n^s:

$$\alpha_{ni}^s = \alpha_i\left(\alpha^s + \varepsilon_n^s\right). \tag{43}$$

We further impose the restriction $\sum_{i=1}^N \alpha_i = 1$. Under the assumption of equation (43), the sectoral expenditure shares from the upper-tier equation (24) becomes:

$$S_n^s = \alpha^s + \overline{\beta}^s y_n + \varepsilon_n^s. \tag{44}$$

This equation is an Engel curve that projects expenditure shares on the adjusted real income.[30] Specifically, it regresses sector expenditure shares on sector dummies and the importer's

29. Later we explore the sensitivity of the results to alternative values of this parameter.

30. Note that sectoral shares in value added and efficiency units are allowed to vary independently from expenditure shares depending on the distribution of sectoral productivities Z_n^s and trade patterns. The sectoral productivities are not estimated and are not needed to perform the counterfactuals.

adjusted real income interacted with sector dummies. The interaction coefficients will have the structural interpretation as the sectoral betas $\overline{\beta}^s$.[31] Using equations (28), (43), and (44), we can write $A^s_{ni} = \alpha_i(S^s_n - S^s_W - \overline{\beta}^s \Omega_n)$, where S^s_W is the share of sector s in world expenditures. Combining this with the gravity equation (41), we reach the following estimating equation:

$$\frac{X^s_{ni}}{Y_n} = \frac{Y^s_i}{Y_W} + \alpha_i(S^s_n - S^s_W) - (\gamma^s \rho^s)D_{ni} + \sum_j \left(\gamma^s \delta^s_j\right) G_{j,ni} + (\beta^s_i - \alpha_i \overline{\beta}^s)\Omega_n + \epsilon^s_{ni} \tag{45}$$

The gravity equation (45) identifies $(\beta^s_i - \alpha_i \overline{\beta}^s)$ using the variation in Ω_n across importers for each exporter. Using the $\overline{\beta}^s$ estimated from the sectoral Engel curve in equation (44) and the α_i estimated from equation (45) we can recover the β^s_i (which is needed to perform the counterfactuals). Since the market shares sum to 1 for each importer, it is guaranteed that $\sum_i \sum_s \beta^s_i = 0$ in the estimation, as the theory requires. We cluster the estimation at the importer level to allow for correlation in the errors across exporters.

The sectoral gravity equation aggregates to the gravity equation of a single-sector model. Summing equation (45) across sectors s gives the total expenditure share dedicated to goods from i in the importing country n,

$$\frac{X_{ni}}{Y_n} = \frac{Y_i}{Y_W} - (\gamma\rho)D_{ni} + \sum_j (\gamma\delta_j) G_{j,ni} + \beta_i \Omega_n + \epsilon_{ni}, \tag{46}$$

where $\gamma\rho \equiv \sum_{s=1}^S \gamma^s \rho^s$, $\beta_i \equiv \sum_{s=1}^S \beta^s_i$, and $\epsilon_{ni} \equiv \sum_{s=1}^S \epsilon^s_{ni}$. We can readily identify equation (46) as the gravity equation that would arise in a single-sector model ($S = 1$). Thus, summing our estimates on the gravity terms from equation (45) will match the gravity coefficients from a single-sector model. Likewise, the sum of the sector-specific income elasticities by exporter $\sum_s \beta^s_i$ estimated from equation (45) matches the income elasticity β_i estimated from equation (46).

31. The term ε^s_i captures cross-country differences in tastes across sectors that are not explained by differences in income or inequality levels. As in Costinot, Donaldson, and Komunjer (2012) or Caliendo and Parro (2012), this flexibility is needed for the model to match sectoral shares by importer. This approach to measuring taste differences is also in the spirit of Atkin (2013), who attributes regional differences in tastes to variation in demand that is not captured by observables.

IV.B. Estimation Results

We begin by estimating the single-sector gravity model in equation (46). This regression aggregates across the sectors in the data, and as illustrated in equation (46), the baseline multisector gravity equation aggregates exactly to this single-sector gravity equation. The results are reported in Table I. Consistent with the literature, we find that bilateral distance reduces trade flows between countries, which is captured by the statistically significant coefficient on D_{ni}. Under the assumption that $\rho = 0.177$, the estimate implies $\gamma = 0.24$ ($= \frac{.043}{.177}$).[32] The additional trade costs—common language and a contiguous border term—also have the intuitive signs.

The table also reports estimates of the 40 β_i parameters, one corresponding to each exporter, in the subsequent rows. The exporters with the highest β's are the United States and Japan, whereas Indonesia and India have the lowest β's. This means that the United States and Japan export goods that are preferred by richer consumers, and the latter export goods preferred by poorer consumers. To visualize the β's, we plot them against the per capita income in Figure I. The relationship is strongly positive and statistically significant. We emphasize that this relationship is not imposed by the estimation. Rather, these coefficients reflect that richer countries are more likely to spend on products from richer countries, conditional on trade costs. We also note that the β's are fully flexible, which is why the coefficients are often not statistically significant, but the null hypothesis that all income elasticities are zero is rejected.[33] Moreover, the finding

32. This estimate is close to the translog gravity equation estimate of $\gamma = 0.167$ estimated by Novy (2012). Feenstra and Weinstein (2010) report a median γ of 0.19 using a different data, level of aggregation and estimation procedure, so our estimate is in line with the few publications that have run gravity regressions with the translog specification.

33. If we reduce the number of estimated parameters by imposing a relationship between income elasticities and exporter income, we find a positive and statistically significant relationship between the two variables. Specifically, we can impose that $\beta_i = B_0 + B_1 y_i$, which is similar to how Feenstra and Romalis (2014) allow for nonhomotheticities. The theoretical restriction $\sum_i \beta_i = 0$ implies that $B_0 = -B_1 \frac{1}{N}\sum_i y_i$, transforming this linear relationship to $\beta_i = B_1\left(y_i - \frac{1}{N}\sum_{i'} y_{i'}\right)$ and reducing the number of income elasticity parameters to be estimated from 40 to 1. If we impose this to estimate the gravity equation, we find $B_1 = 0.0057$ (standard error of 0.0026). This estimate is very close to regressing our estimated β_i's reported in Table I on $\left(y_i - \frac{1}{N}\sum_{i'} y_{i'}\right)$, which yields a coefficient of 0.008 (standard error of 0.0035).

TABLE I

GRAVITY ESTIMATES: SINGLE SECTOR

Variables	(1A)		(1B)
$-\text{Distance}_{ni}$	0.043***		
	(0.005)		
Language_{ni}	0.131***		
	(0.021)		
Border_{ni}	0.135***		
	(0.023)		
$\Omega_n\ X$		$\Omega_n\ X$	
β-USA	0.052**	β-POL	−0.001
	(0.022)		(0.011)
β-JPN	0.028***	β-IDN	−0.023
	(0.008)		(0.032)
β-CHN	0.008	β-AUT	−0.001
	(0.031)		(0.009)
β-DEU	−0.015	β-DNK	0.003
	(0.013)		(0.009)
β-GBR	0.005	β-GRC	0.018*
	(0.013)		(0.009)
β-FRA	−0.013	β-IRL	−0.009
	(0.011)		(0.013)
β-ITA	0.006	β-FIN	0.013
	(0.006)		(0.010)
β-ESP	−0.004	β-PRT	−0.001
	(0.006)		(0.005)
β-CAN	−0.017	β-CZE	−0.003
	(0.015)		(0.006)
β-KOR	0.006	β-ROM	0.003
	(0.012)		(0.015)
β-IND	−0.048	β-HUN	0.008
	(0.042)		(0.012)
β-BRA	−0.010	β-SVK	0.005
	(0.017)		(0.010)
β-RUS	−0.003	β-LUX	−0.012*
	(0.022)		(0.007)
β-MEX	−0.029*	β-SVN	−0.002
	(0.017)		(0.005)
β-AUS	0.011	β-BGR	0.004
	(0.012)		(0.016)
β-NLD	−0.008	β-LTU	0.004
	(0.009)		(0.010)
β-TUR	0.006	β-LVA	0.006
	(0.016)		(0.009)
β-BEL	−0.025**	β-EST	0.007
	(0.011)		(0.007)
β-TWN	0.017	β-CYP	0.016**
	(0.011)		(0.008)
β-SWE	0.006	β-MLT	−0.006
	(0.008)		(0.010)
Joint F-test p-value for income elasticities		0.00	
R^2		0.47	
Observations		1,600	
Implied γ		0.24	

Notes. Table reports the estimates of the single-sector gravity equation that aggregates the data across the 35 sectors. There are 40 income elasticity parameters β_i. We assume that $\rho = 0.177$, and the implied $\gamma = \frac{\{\text{coefficient on } - \text{Distance}_{ni}\}}{\rho}$ is noted at the bottom of the table. Standard errors are clustered by importer. Significance * .10, ** .05, *** .01.

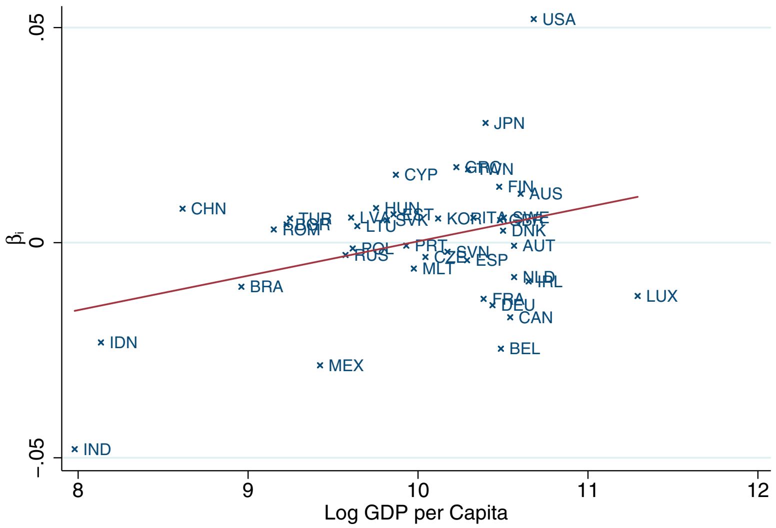

FIGURE I

β_i and GDP per Capita

Figure plots exporter income elasticity against its per capita GDP.

that a subset are statistically significant is sufficient to reject homothetic preferences in the data and is consistent with the existing literature that finds that richer countries export goods with higher income elasticities.[34]

Next we report the results for the multisector estimation. As noted earlier, the analysis involves estimating the Engel curve in equation (44), which projects sectoral expenditure shares on adjusted real income across countries. Table II reports the sectoral betas, $\overline{\beta}^s$. Compared to food and manufacturing sectors (listed in column (1A)), service sectors (listed in column (1B)) tend to be high-income elastic.[35] This pattern can be visualized by plotting countries' expenditure shares in these three broad categories

34. See Hallak (2006), Khandelwal (2010), Hallak and Schott (2011), and Feenstra and Romalis (2014).

35. To see this, we aggregate the $\overline{\beta}^s$ into three categories: food includes "Agriculture" and "Food, Beverages, and Tobacco," manufacturing includes the remaining sectors listed in column (1A) of Table II, and services is composed of the 19 sectors in column (1B). The corresponding elasticities for food, manufacturing, and services are −0.0343, −0.0410, and 0.0753, respectively. (Again, the sum of these three broad classifications is 0.)

TABLE II

Engel Curve Estimation: Baseline

Variables	(1A)		(1B)
Agriculture	−0.0218***	Electricity, gas, and water supply	−0.0033
	(0.002)		(0.002)
Mining	−0.0080***	Construction	−0.0053
	(0.002)		(0.003)
Food, beverages, and tobacco	−0.0125***	Sale, repair of motor vehicles	0.0027***
	(0.003)		(0.001)
Textiles	−0.0063***	Wholesale trade and commission trade	0.0010
	(0.001)		(0.003)
Leather and footwear	−0.0009***	Retail trade	−0.0020
	(0.000)		(0.002)
Wood products	−0.0008	Hotels and restaurants	0.0021
	(0.001)		(0.001)
Printing and publishing	0.0014*	Inland transport	−0.0089***
	(0.001)		(0.003)
Coke, refined petroleum, nuclear fuel	−0.0056***	Water transport	−0.0007
	(0.002)		(0.001)
Chemicals and chemical products	−0.0046***	Air transport	0.0007*
	(0.001)		(0.000)
Rubber and plastics	−0.0016*	Other auxiliary transport activities	0.0038***
	(0.001)		(0.001)
Other nonmetallic minerals	−0.0027***	Post and telecommunications	0.0012
	(0.001)		(0.001)
Basic metals and fabricated metal	−0.0031	Financial intermediation	0.0280
	(0.004)		(0.018)
Machinery	−0.0028	Real estate activities	0.0095***
	(0.002)		(0.003)
Electrical and optical equipment	−0.0021	Renting of M&Eq	0.0243***
	(0.003)		(0.003)
Transport equipment	−0.0033*	Public admin and defense	0.0038
	(0.002)		(0.003)
Manufacturing, nec	−0.0005	Education	0.0022**
	(0.001)		(0.001)
		Health and social work	0.0128***
			(0.003)
		Other community and social services	0.0031
			(0.003)
		Private households with employed persons	0.0003**
			(0.000)
Sector FEs		yes	
Joint F-test p-value for sectoral elasticities		0.00	
R^2		0.67	
Observations		1,400	

Notes. Table reports the sectoral income elasticities from the Engel curve equation. It is a regression of importers' sectoral expenditures shares on the adjusted real income interacted with sector dummies. Sectors Agriculture and Food, beverages, and tobacco are the food sectors, and the remaining sectors in column (1A) are the manufacturing sectors; the service sectors are listed in column (1B). The regression also includes sector fixed effects. Standard errors are clustered by importer. Significance * .10, ** .05, *** .01.

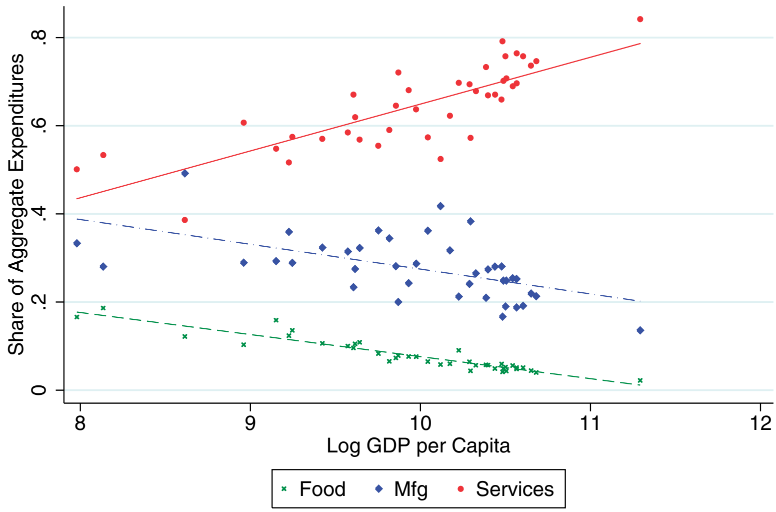

FIGURE II

Engel Curves by Broad Sector Groups

Figure displays Engel curves of expenditure shares in broad sectors against per capita GDP. See the note in Table II for the list of sectors.

against their income per capita in Figure II: the Engel curve for services is positively sloped, whereas it is negatively sloped for food and manufacturing.[36] These sectoral elasticities are highly correlated with sectoral elasticities estimated using a different non-homothetic framework on different data by Caron, Fally, and Markusen (2014); see Appendix Figure A.1, which plots the two sets of elasticities against each other.[37]

The results of the sectoral gravity equation in equation (45) is reported in Table III. Columns (1A) and (1B) report the 35 sector-specific distance coefficients, $\rho\gamma^s$ (where $\rho = 0.177$ as before). Recall, these these coefficients sum to coefficient on distance from the single-sector model (see Table I). Likewise, the sector-specific language and border coefficients in columns (2) and (3) of Table III sum exactly to the corresponding coefficients in the single-sector estimation.

36. This is consistent with the literature on structural transformation; see Herrendorf, Rogerson, and Valentinyi (2014).

37. Caron, Fally, and Markusen (2014) estimate sectoral income elasticities on GTAP data using constant relative income preferences. We match GTAP sector classifications with WIOD sector classifications to produce the scatter plot.

TABLE III

SECTORAL GRAVITY ESTIMATES: BASELINE

Variables	(1A) −Distance	(2A) Language	(3A) Border		(1B) −Distance	(2B) Language	(3B) Border
Agriculture	0.0011***	0.0054***	0.0049***	Electricity, gas, and water supply	0.0012***	0.0051***	0.0046***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.001)	(0.001)
Mining	0.0006***	0.0016***	0.0022***	Construction	0.0038***	0.0135***	0.0129***
	(0.000)	(0.000)	(0.001)		(0.001)	(0.002)	(0.002)
Food, beverages, and tobacco	0.0016***	0.0061***	0.0061***	Sale, repair of motor vehicles	0.0005***	0.0025***	0.0022***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.000)	(0.000)
Textiles	0.0004***	0.0012***	0.0014***	Wholesale trade and commission trade	0.0020***	0.0082***	0.0072***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Leather and footwear	0.0001***	0.0002***	0.0002***	Retail trade	0.0018***	0.0060***	0.0059***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Wood products	0.0002***	0.0011***	0.0011***	Hotels and restaurants	0.0013***	0.0037***	0.0037***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Printing and publishing	0.0007***	0.0020***	0.0024***	Inland transport	0.0008***	0.0047***	0.0045***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Coke, refined petroleum, nuclear fuel	0.0008***	0.0023***	0.0032***	Water transport	0.0001***	0.0002***	0.0002**
	(0.000)	(0.001)	(0.001)		(0.000)	(0.000)	(0.000)
Chemicals and chemical products	0.0013***	0.0016***	0.0022***	Air transport	0.0002***	0.0004***	0.0005***
	(0.000)	(0.000)	(0.001)		(0.000)	(0.000)	(0.000)
Rubber and plastics	0.0005***	0.0010***	0.0013***	Other auxiliary transport activities	0.0004***	0.0025***	0.0024***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)
Other nonmetallic minerals	0.0005***	0.0016***	0.0016***	Post and telecommunications	0.0010***	0.0033***	0.0034***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Basic metals and fabricated metal	0.0018***	0.0036***	0.0042***	Financial intermediation	0.0031***	0.0056***	0.0064***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.001)	(0.001)

TABLE III
(CONTINUED)

Variables	(1A) −Distance	(2A) Language	(3A) Border		(1B) −Distance	(2B) Language	(3B) Border
Machinery	0.0009***	0.0015***	0.0016***	Real estate activities	0.0031***	0.0097***	0.0096***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.002)	(0.002)
Electrical and optical equipment	0.0014***	0.0014**	0.0017***	Renting of M&Eq	0.0027***	0.0097***	0.0103***
	(0.000)	(0.001)	(0.000)		(0.000)	(0.002)	(0.002)
Transport equipment	0.0011***	0.0019***	0.0027***	Public admin and defence	0.0029***	0.0073***	0.0078***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.001)	(0.001)
Manufacturing, nec	0.0003***	0.0009***	0.0011***	Education	0.0011***	0.0045***	0.0040***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
				Health and social work	0.0017***	0.0061***	0.0064***
					(0.000)	(0.001)	(0.001)
				Other community and social services	0.0018***	0.0044***	0.0048***
					(0.000)	(0.001)	(0.001)
				Private households with employed persons	0.0001**	0.0002***	0.0002***
					(0.000)	(0.000)	(0.000)
Ω_n × sector-exporter dummies			not displayed				
Joint F-test p-value for income elasticities			0.00				
R^2			0.40				
Observations			56,000				

Notes. Table reports the estimates of the sectoral gravity equation. The results report sector-specific coefficients on (the negative of) distance, language and border in columns (1), (2), and (3), respectively. The sum of these coefficients exactly sum to the corresponding coefficients in Table I. The table supresses the sector-exporter interaction coefficients to save space, but recall that the sum of these coefficients across sectors equals sectoral coefficients in Table II, and the sum of the coefficients for each exporter across sectors equals the country-specific coefficients in Table I. Standard errors are clustered by importer. Significance * .10, ** .05, *** .01.

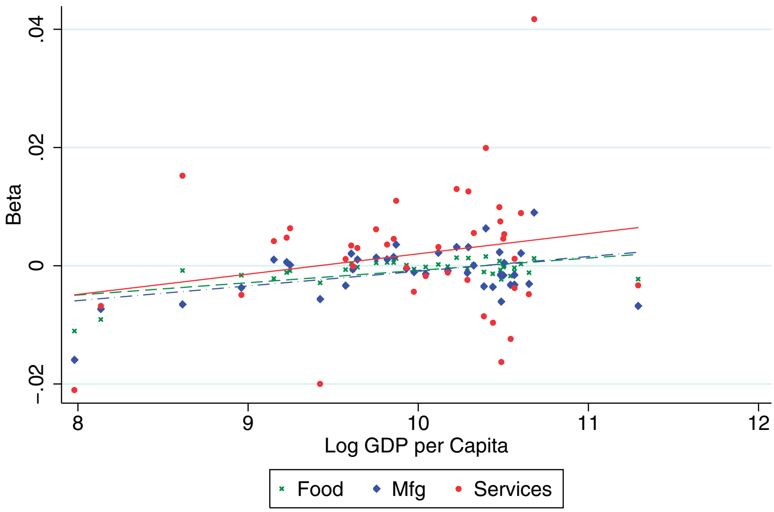

FIGURE III

β by Exporter and Broad Sector Group versus GDP per Capita

Figure plots income elasticities, summed across broad sectors for each country, against per capita GDP. See the note in Table II for the list of sectors.

We suppress the estimates of $\{\beta_n^s\}$ for readability purposes, but recall that $\sum_s \beta_i^s$ equals the exporter income elasticities β_i reported in the single-sector gravity equation. Also note that by construction, $\sum_n \beta_n^s$ equals the sectoral elasticities $\overline{\beta}^s$ displayed in Table II. To see how β_n^s relate to exporter income per capita, we aggregate these coefficients to three broad classifications—food, manufacturing, and services—and report the plot in Figure III. Analogous to the single-sector estimates in Figure I, we find that the positive relationship between exporter income per capita and income elasticities holds within sectors as well.

V. THE UNEQUAL GAINS FROM TRADE

This section conducts counterfactual analyses to measure the distributional consequences of trade. Section V.A explains how we numerically implement the expressions from Section III.C. Section V.B shows the results of autarky counterfactuals in the single-sector version of our model. Section V.C presents the main results: the autarky counterfactuals in the baseline multisector model. Section V.D presents a series of robustness checks. In Section V.E, we conduct counterfactuals of partial changes in foreign trade costs.

V.A. Computing Consumer-Specific Welfare Changes

To measure the unequal distribution of the gains from trade across consumers, we perform the counterfactual experiment of changing trade costs. The main results bring consumers in each country to autarky, and we also simulate partial changes in trade costs. Because we know the changes in expenditure shares that take place between the observed trade shares and the counterfactual scenarios, we can use the results from Section III.C to measure the welfare change experienced by consumers at each income level. But before applying these results, a few considerations are in order.

First, we highlight that throughout the analysis we take as given the specialization pattern of countries across goods with different income elasticity. That is, the β_n^s are not allowed to change in counterfactual scenarios. These patterns could change as trade costs change, but we note that the direction of the change will depend on what forces determine specialization across goods with different income elasticity.[38]

Second, the restriction to nonnegative individual expenditure shares may bind in some instances. Therefore, to compute expression (40) for the welfare change $\omega_{n,h}^{tr \to cf}$ of each consumer h from country n between the initial scenario under trade (*tr*) and each counterfactual scenario (*cf*), we must first compute consumer-specific reservation prices. Following Feenstra (2010), this amounts to setting the individual expenditure shares of dropped varieties to zero according to equation (23), and substituting reservation prices back into the consumed varieties. We then numerically integrate equations (32)–(36) between the aggregate expenditure shares for country n in equation (22) evaluated at those reservation prices. As this procedure is done for each

38. If specialization is demand-driven by home-market effects, as in Fajgelbaum, Grossman, and Helpman (2011), poor countries would specialize less in low-income elastic goods as trade costs increase. However, if specialization is demand-driven in a neoclassical environment as in Mitra and Trindade (2005), or determined by relative factor endowments, as in Schott (2004) or Caron, Fally, and Markusen (2014), the opposite would happen. To our knowledge, no study has established the relative importance of these forces for international specialization patterns in goods with different income elasticity.

consumer h separately, we add a subscript h to the terms in equation (40) to denote that the aggregate expenditure shares used to construct the welfare change of each consumer are consumer-specific:

$$\omega_{n,h}^{tr\to cf} = \left(\frac{W_{n,h}^{cf}}{W_{n,h}^{tr}}\right)\left(\frac{x_h}{\tilde{x}_n}\right)^{-\ln\left(\frac{b_{n,h}^{cf}}{b_{n,h}^{tr}}\right)}. \tag{47}$$

We describe these steps formally in Appendix A.

Finally, we assume, as with the gravity estimation, that the expenditure distribution in country n is log-normal with variance σ_n^2. This allows mapping the observed Gini coefficient to the Theil index. Henceforth, we index consumers by their percentile in the income distribution, so that $h \in (0, 1)$. Under the log-normal distribution, the expenditure level of a consumer at percentile h in country i is $e^{z_h\sigma_i+\mu_i}$, where z_h denotes the value from a standard normal z-table at percentile h, and $\tilde{x}_i = e^{\sigma_i+\mu_i}$. We can therefore rewrite equation(47) as:

$$\omega_{n,h}^{tr\to cf} = \left(\frac{W_{n,h}^{cf}}{W_{n,h}^{tr}}\right)\left(\frac{b_{n,h}^{cf}}{b_{n,h}^{tr}}\right)^{\sigma_n(1-z_h)}. \tag{48}$$

Consumers at percentile h are willing to pay a fraction $1-\omega_{n,h}^{tr\to cf}$ of their income under trade to avoid the movement from the trade to the counterfactual scenario when $\omega_{n,h}^{tr\to cf} < 1$.

V.B. *Single-Sector Analysis*

To convey some intuition, we first report results from the single-sector version of the model using the parameters from Table I. Figure IV plots the gains from trade by percentile of the income distribution for all the countries in our data (i.e., it plots $1-\omega_{n,h}^{tr\to cf}$ for $\omega_{n,h}^{tr\to cf}$ defined in equation (48) for all n and $h = \{0.01, ..., 0.99\}$ when each country is moved to autarky). To facilitate the comparisons across countries, we express the gains from trade of each percentile as difference from the gains of the 50th percentile in each country. The solid line in the figure shows the average for each percentile across the 40 countries in our sample.

The typical U-shape relationship between the gains from trade and the position in the income distribution implies that poor and rich consumers within each country tend to reap larger benefits from trade compared to middle-income consumers.

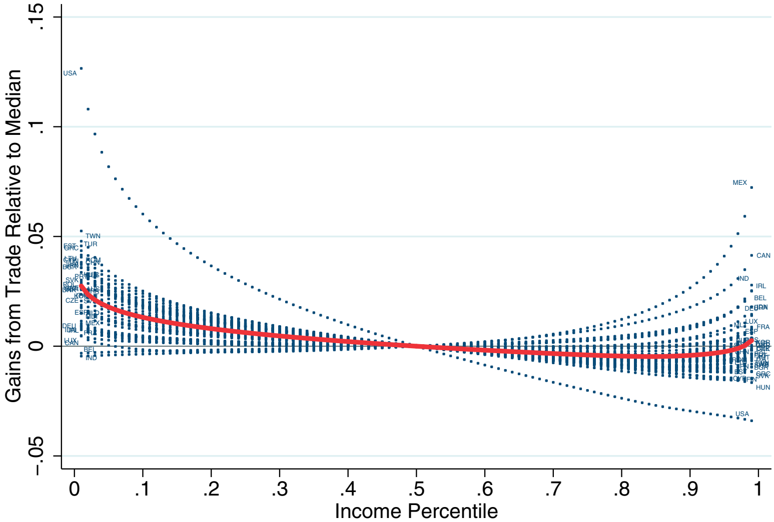

FIGURE IV

Distribution of Unequal Gains: Single-Sector Case

The deviations are relative to the median individual. The solid line is the average across countries.

The reason for these patterns is intuitive in the light of the earlier discussion of equation (38) for the change in the relative price of high-income elastic goods. In a movement to autarky, the change in the relative price of high-income elastic goods experienced by the representative agent of country n is:

$$\ln\left(\frac{b_n^{cf}}{b_n^{tr}}\right) = \frac{1}{\gamma}\left(\sigma_\beta^2\left(y_n^{cf} - y_n^{tr}\right) - \left(\beta_n - \overline{\beta}_n\right)\right). \tag{49}$$

The formula reveals that a key determinant of the bias of trade is the income elasticity of each country's exports relative to each country's imports, captured by $\beta_n - \overline{\beta}_n$.[39] A positive $\beta_n - \overline{\beta}_n$ implies that expenditures move toward higher income elastic goods in a movement to autarky, potentially implying a reduction in their relative price. Therefore, for low-income (high-income) countries which tend to be exporters of low- (high-) income elastic goods as shown in Figure I, trade

39. A decomposition of equation (49) reveals that the second term inside the parentheses accounts for majority of the variation, 80.7%. The first term accounts for only 13.9%, and the covariance for the remaining 5.4%.

openness relatively favors rich (poor) individuals.[40] In countries that export products with intermediate income elasticities, middle-income consumers benefit the least from trade because their home country already supplies these goods; at the same time, opening to trade supplies both the rich and poor with products that better match their tastes. This creates a U-shaped pattern of the gains from trade for the typical country in the single-sector model.

V.C. *Multisector Analysis*

We now present the baseline results from the multisector model. We first report the aggregate gains from trade, defined as the gains for the representative agent in each country. Columns (1A) and (1B) of Table IV report the real income loss for the representative consumer in each country.[41] We compare these results to a homothetic case by setting $\beta_n^s = 0$ for all n and s in the gravity estimation and reestimating the remaining parameters; this amounts to estimating a translog multisector gravity equation. The translog gravity estimates are reported in Appendix Table A.1; the results reveal that the estimated gravity coefficients hardly change under the constraint that preferences are homothetic (compare Table III with Appendix Table A.1). As a result, the aggregate gains under the translog specification, reported in columns (2A) and (2B) of Table IV, are very similar to the aggregate gains under the nonhomothetic AIDS. This suggests that, in our context, nonhomotheticicities do not fundamentally change the estimates of the *aggregate* gains from trade.[42] However, as we discuss next, they have a strong impact on the bias of the gains from trade across consumers.

40. When the economy is in autarky, all foreign goods are dropped and demand for the domestic variety corresponds to a single-good AIDS with unitary income elasticity; see Feenstra (2010). However, the parameter β_n still enters in equation (49) because it measures the *difference* in relative prices between the actual trade scenario and the autarky prices.

41. The aggregate gains from trade in the multi-sector setting are higher than the single-sector case. This is consistent with Ossa (2015) and Costinot and Rodríguez-Clare (2014) who show that allowing for sectoral heterogeneity leads to larger measurement of the aggregate gains from trade in CES environments.

42. We note that this statement relies on defining the aggregate gains as those of the representative consumer. An alternative, which we do not pursue here, would be to define the aggregate gains as the average change in real income, $\frac{1}{H}\sum_h \omega_{n,h}^{tr\rightarrow cf} x_h$. This would correspond to the amount of income per capita needed to leave every consumer indifferent between trade and autarky.

TABLE IV

AGGREGATE GAINS (%) FROM TRADE: AIDS VERSUS TRANSLOG

Country	(1A) Aggregate Gains (AIDS)	(2A) Aggregate Gains (Translog)	(3A) Gains at Median (AIDS)	(4A) Country Import Share	Country	(1B) Aggregate Gains (AIDS)	(2B) Aggregate Gains (Translog)	(3B) Gains at Median (AIDS)	(4B) Country Import Share
AUS	9	8	24	8	IRL	40	43	52	32
AUT	42	41	56	23	ITA	13	12	31	10
BEL	50	51	63	28	JPN	6	5	24	5
BGR	46	45	58	25	KOR	16	16	33	11
BRA	2	2	20	4	LTU	67	64	77	27
CAN	29	30	44	16	LUX	86	85	89	49
CHN	6	7	16	7	LVA	36	35	52	22
CYP	43	40	57	22	MEX	24	24	40	14
CZE	50	49	60	26	MLT	66	66	75	34
DEU	26	26	40	17	NLD	28	28	45	21
DNK	41	40	54	22	POL	27	26	42	18
ESP	17	16	34	12	PRT	27	26	46	17
EST	50	48	65	27	ROM	34	33	49	19
FIN	28	26	46	17	RUS	16	16	32	9
FRA	15	15	29	12	SVK	67	64	74	30
GBR	14	13	33	12	SVN	55	54	66	27
GRC	26	24	44	15	SWE	29	27	43	19
HUN	68	67	76	31	TUR	11	11	29	10
IDN	5	5	11	8	TWN	41	41	56	20
IND	6	6	10	6	USA	8	6	37	6
Average	32	31	46	18					

Notes. Table reports gains from trade. The first and third columns report the gains for the representative agent and median consumer, respectively, using the estimated parameters from Tables II and III. The second column computes welfare changes using a translog demand system; these parameters are obtained from rerunning the gravity equation imposing ${\beta^s}_i = 0$ (see Appendix Table A.1). The fourth column reports the aggregate import share for each country.

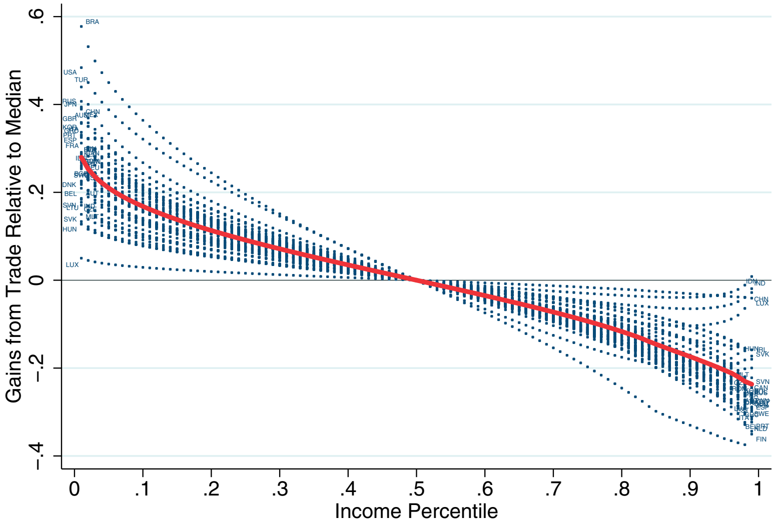

FIGURE V

Distribution of Unequal Gains: Baseline Case

The deviations are relative to the median individual. The solid line is the average across countries.

Figure V reports the unequal gains from trade with multiple sectors across percentiles using the parameters from Tables II and III. As before, the figure shows the gains from trade for each percentile in each country as a difference from the median percentile of each country. Table V reports the absolute gains from trade at the 10th, median, and 90th percentile, as well as for the representative consumer of each country (which is identical to column (1) of Table IV).

There are two important differences between the results under the single- and the multisector frameworks. First, the relative effects across percentiles are considerably larger. In the single-sector case from Figure IV, the gains from trade (relative to the median) lie within the −5% to 10% band across most countries and percentiles, whereas in the multisector case the range increases to −40% to 60%. Second, poor consumers are now predicted to gain more from trade than rich consumers in every country. Every consumer below the median income gains more from trade than every consumer above the median. On average across the countries in our sample, the gains from trade are 63% at the

TABLE V

UNEQUAL GAINS FROM TRADE (%): BASELINE

Country	(1A) 10th Percentile	(2A) 50th Percentile	(3A) Aggregate Gains	(4A) 90th Percentile	Country	(1B) 10th Percentile	(2B) 50th Percentile	(3B) Aggregate Gains	(4B) 90th Percentile
AUS	45	24	9	5	IRL	67	52	40	38
AUT	68	56	42	38	ITA	52	31	13	8
BEL	75	63	50	46	JPN	46	24	6	2
BGR	72	58	46	43	KOR	53	33	16	12
BRA	57	20	2	3	LTU	87	77	67	63
CAN	60	44	29	25	LUX	91	89	86	85
CHN	38	16	6	6	LVA	70	52	36	32
CYP	71	57	43	39	MEX	65	40	24	21
CZE	71	60	50	47	MLT	83	75	66	64
DEU	56	40	26	21	NLD	61	45	28	24
DNK	67	54	41	37	POL	61	42	27	23
ESP	53	34	17	12	PRT	67	46	27	22
EST	79	65	50	46	ROM	67	49	34	31
FIN	64	46	28	23	RUS	56	32	16	14
FRA	45	29	15	11	SVK	82	74	67	64
GBR	54	33	14	10	SVN	76	66	55	52
GRC	63	44	26	21	SWE	59	43	29	25
HUN	84	76	68	65	TUR	56	29	11	8
IDN	24	11	5	4	TWN	72	56	41	37
IND	19	10	6	6	USA	69	37	8	4
Average	63	46	32	28					

Notes. Table reports gains from trade for the baseline multisector model and uses the parameters reported in Tables II and III. The columns report welfare changes associated at the 10th, 50th, the representative consumer (taken from column (1) of Table IV), and the 90th percentiles.

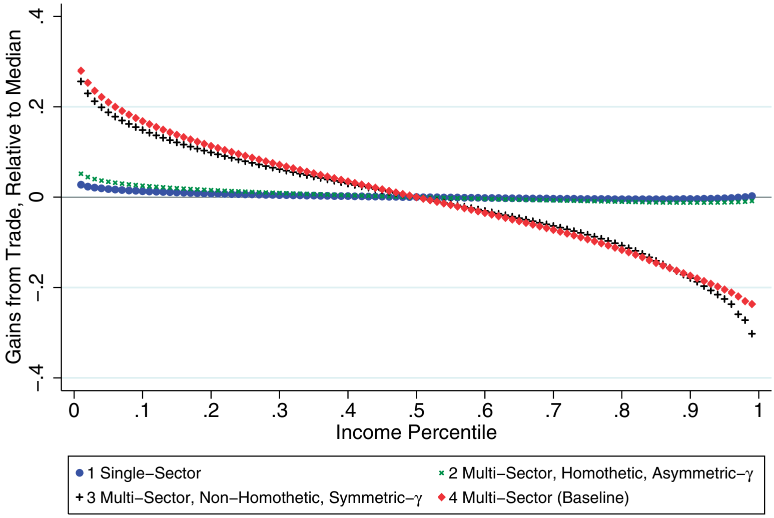

FIGURE VI

Comparison of Distribution of Unequal Gains, Means across Countries

The deviations are relative to the median individual. Figure shows averages across countries, by percentile.

10th percentile of the income distribution and 28% at the 90th percentile.

Why do the results for the multisector analysis differ from the single-sector analysis? The multisector model allows for two key additional margins that influence the propoor bias of trade: heterogeneity in the elasticity of substitution $\{\gamma_s\}$ and in the sectoral betas $\{\overline{\beta}^s\}$. By construction, if we restricted the $\{\gamma_s\}$ and $\{\beta_n^s\}$ to be constant across sectors in the multisector estimation, we would recover the same unequal gains from trade as in the single-sector estimation, and Figure V would look identical to Figure IV. To gauge the importance of each of these margins in shaping the unequal gains, Figure VI shows the average gains from trade by percentile across all countries for four models: (i) the single-sector model (which is equal to the solid curve in Figure IV); (ii) a multisector model with homothetic sectors that imposes $\overline{\beta}^s = 0$ for all s but allows for heterogeneous γ's; (iii) a multisector model that imposes symmetric γ's ($\gamma_s = \frac{1}{J}\gamma$) but allows for nonhomothetic sectors; and (iv) the baseline multisector model that allows for nonhomothetic sectors and sector-specific γ's (which is equal to the solid curve in Figure V).

We find that including nonhomotheticities across sectors (i.e., comparing models 1 versus 3 or models 2 versus 4) is crucial for the strongly propoor bias of trade. The reason is that low-income consumers spend relatively more on sectors that are more traded, whereas high-income consumers spend relatively more on services, which are among the least internationally traded sectors. Recall from Figure II that the income elasticities of the service sectors are higher than nonservice sectors; in addition, the average import share among the service sectors is 6.4% compared to 20% and 48% for food and manufacturing sectors, respectively. We also find that including heterogeneity in γ_s across sectors (i.e., comparing models 1 versus 2, or models 3 versus 4) slightly biases the gains from trade toward poor consumers. The reason is that low-income consumers concentrate spending on sectors with a lower substitution parameter γ_s. To see this, we construct, for each percentile in each country, an expenditure-share weighted average of the sectoral gammas. Then, we average across all countries and report the results in Appendix Figure A.2. The figure reveals that higher percentiles concentrate spending in sectors where exporters sell more substitutable goods. In sum, larger expenditures in more tradeable sectors and a lower rate of substitution between imports and domestic goods lead to larger gains from trade for the poor than the rich.

Although the gains from trade are larger for the poor in every country, we also observe cross-country heterogeneity in the difference between the gains from trade of poor and rich consumers. What determines the strength in the propoor bias of trade? As in the single-sector case, the answer lies in part in the income elasticity of each country's products vis-à-vis its natural trade partners. In countries that export relatively low income-elastic goods, such as India, the gains from trade are relatively less biased to poor consumers. In these countries, opening to trade increases the relative price of low-income elastic goods (which are exported), or decreases that of high-income elastic goods (which are imported). This can be seen in Figure VII, which plots the difference between the gains from trade of the 90th and 10th percentiles against each country's income elasticity ($\beta_n = \sum_s \beta_n^s$). The difference between the gains from trade of the 90th and 10th percentiles is more negative in countries with higher income elasticity of exports. However, the income elasticity of the goods exported by each country is not sufficient to

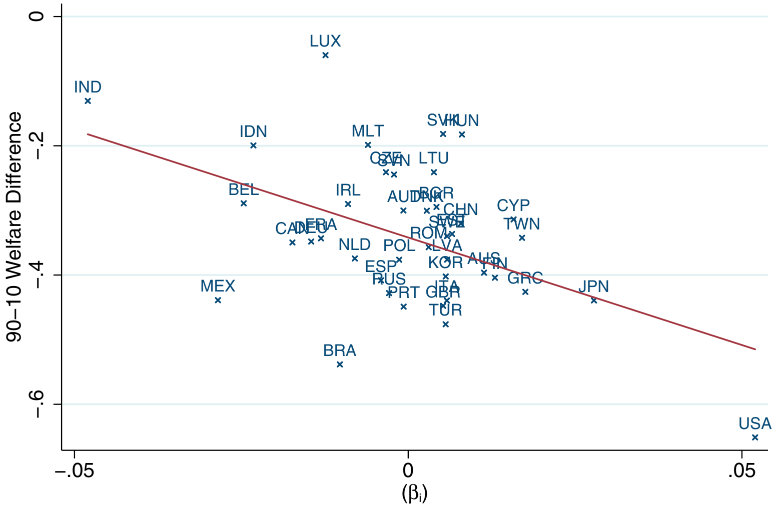

FIGURE VII

Difference in Gains from Trade between 90th and 10th Percentiles versus β_i

Figure plots the difference in gains between 90th and 10th percentiles

determine the bias of trade, which also depends on the distribution of expenditures across goods with different income elasticity, as implied by (35).[43]

V.D. Robustness

This section examines the robustness of our baseline results to alternative specifications.

1. Sectoral Income Elasticities $\overline{\beta}^s$. The first set of robustness checks examines the robustness of estimating the $\overline{\beta}^s$ using the Engel curve regression in equation (44).

An assumption in our framework is that individual preferences are identical across countries.[44] This assumption is

43. If the United States and India are excluded from the figure, the relationship remains negative but not significant. This suggests that although the income elasticity of a country's products matters, the other terms in equation (35) also influence the overall bias of trade.

44. Note that we do allow for some heterogeneity in preferences across countries through the parameter α_{in}^s, which is reflected in the term ε_n^s of the Engel curve equation (44).

standard in models of international trade and in quantitative analyses of these models. A second assumption, which results from the structure of the price elasticities in equation (21), is that relative prices do not affect sectoral expenditure shares in equation (44) other than through the homothetic component $a(p)$ (and only so if nonhomotheticities are present). As a result, equation (44) for the aggregate shares has an "extended Cobb-Douglas" form consisting of a constant plus a slope with respect to income. This property of the model is also similar to the majority of multisector trade models that assume Cobb-Douglas preferences across sectors. Our approach to estimating the Engel curves using cross-country data is consistent with these assumptions. Under these two assumptions, the slopes of Engel curves across consumers within a country are the same as the slopes of the Engel curves that we estimate using aggregate data across countries. This motivates the following two robustness checks.

First, we reestimate the Engel curve slopes from equation (44) using variation over time by including country-sector fixed effects, rather than just sector fixed effects. This specification controls for time invariant differences in country characteristics, and in principle, may result in very different estimates of the $\overline{\beta}^s$ parameters.[45] However, the $\overline{\beta}^s$ estimated using the specification with country-sector fixed effects are positively correlated with the baseline estimates (the correlation between the estimates is 0.68). Figure VIII compares the welfare gains, averaged across countries, using these alternative sectoral elasticities with the baseline results, resulting in very similar patterns.

As a second robustness check, we estimate the sectoral elasticities relying on consumer-level microdata. This check addresses the concern that variation in consumer expenditures within countries may not be accurately reflected in aggregate expenditures across countries.[46] We use the 2013 U.S. Consumer Expenditure Survey (CE) microdata that records expenditures to estimate the

45. We use an average of bilateral flows between 1995 and 1997 as the initial year to smooth out annual shocks.

46. For example, Bee, Meyer, and Sullivan (2012) discusses inconsistencies between aggregation of consumer expenditure surveys and national accounts data in the United States.

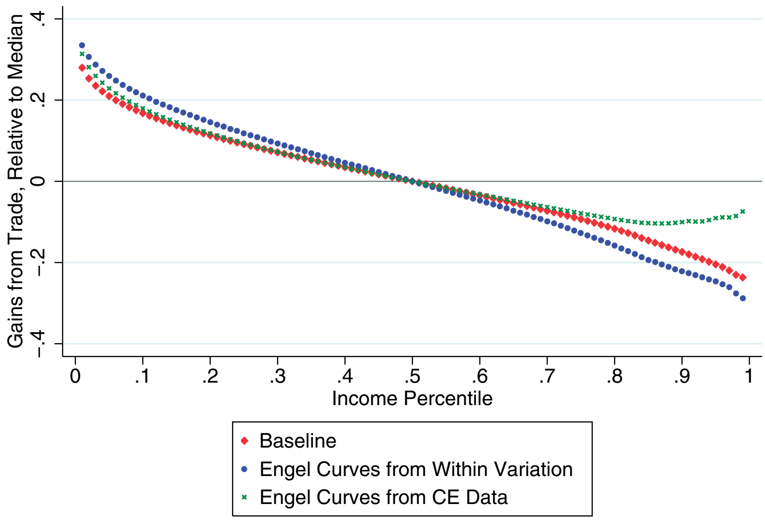

FIGURE VIII

Varying Sectoral Income Elasticities

The deviations are relative to the median individual. Figure shows averages across countries, by percentile.

$\overline{\beta}^s$ from the consumer-level version of equation (44) implied by the model,[47]

$$s^s_{n,h} = \zeta^s_n + \overline{\beta}^s \ln(x_h) + \varepsilon^s_n,$$

where $\zeta^s_n \equiv \alpha^s - \overline{\beta}^s \ln(a_n)$ and h refers to a household in the CE data. To cleanly map the categories in the CE with the sectors in the aggregate data, we classify household expenditures into three broad categories—food, manufacturers, and services.[48] We find $\overline{\beta}^{food,CE} = -0.057$ (std. err. $= 0.00009$), $\overline{\beta}^{mfg,CE} = 0.0375$ (std. err. $= 0.0012$), and $\overline{\beta}^{service,CE} = 0.0197$ (std. err. $= 0.001$).

47. If the CE recorded expenditures by country of origin and/or prices, it would be possible to use these data to estimate obtain estimates of β^s_n and/or γ^s.

48. We use the 2013 quarterly level summary expenditure files: fmli132.dta, fmli133.dta, fmli134.dta, and fmli141.dta. We analyze consumption in the current quarter and construct the categories as follows. Food is the sum of {foodcq alcbevcq, tobacccq}. Manufactured goods is the sum of {apparcq, cartkncq, cartkucq, othvehcq, gasmocq, tvrdiocq, otheqcq, predrqcq, medsupcq, houseqcq, misccq}. Services is the sum of {vehfincq, mainrpcq, vehinscq, vrntlocq, pubtracq, feeadmcq, hlthincq, medsrvcq, sheltcq, utilcq, housopcq, perscacq, readcq, educacq, cashcocq, perinscq}.

Compared to baseline Engel curves, the microdata reveal a positive income elasticity for manufactures, and a somewhat flatter (though still positive) income elasticity for services. We then reestimate the remaining parameters of the model from the gravity equation (27) imposing these sectoral betas and recompute the gains from trade using the same aggregate data as in the baseline case.

The results are presented in Figure VIII. Consistent with the baseline results, the poorest consumers gain more from trade than the median does. The reason is that in both the CE and aggregate data, the Engel curve on food sectors is negative and has low γ^s. The main difference is revealed at the top of the expenditure distribution. In the baseline results, we generally find that the rich gain less than the median-income consumer. But when we estimate the sectoral income elasticities using the the CE data, the average curve bends upward at higher income levels. This is because manufacturing sectors have a higher income elasticity in the CE data and are also more tradeable (relative to services). As a result, using sectoral income elasticities from microdata reveals a slightly different bias of trade relative to the baseline case.

2. Price Elasticity of Service Sectors and Nontradeability. The second set of robustness checks alter the assumptions on the degree of tradeability of some of the service sectors in the data. As discussed earlier, the high elasticity parameters γ^s in service sectors partly affect the bias of the unequal gains. These parameters were obtained by first identifying $\rho^s\gamma^s$ from the semi-elasticity of trade with respect to distance in the gravity equation (45), and then setting $\rho^s = 0.177$ for all sectors. However, one might expect ρ^s to be higher for some service sectors that are essentially nontraded, which would lead us to overestimate the value of γ^s these sectors.[49]

We perform two robustness checks to address this concern. In the first, we increase the value of ρ by 25% to 0.221 for the 12 service sectors that have, on average across countries, expenditures on imports of less than 10%.[50] By increasing ρ for these

49. Anderson, Milot, and Yotov (2012) show that geographic barriers are a stronger deterrent of trade of some services trade than of goods trade.

50. These sectors are: electricity, gas, and water; construction; motor vehicle sales and maintenance; wholesale trade; retail trade; hotels and restaurants;

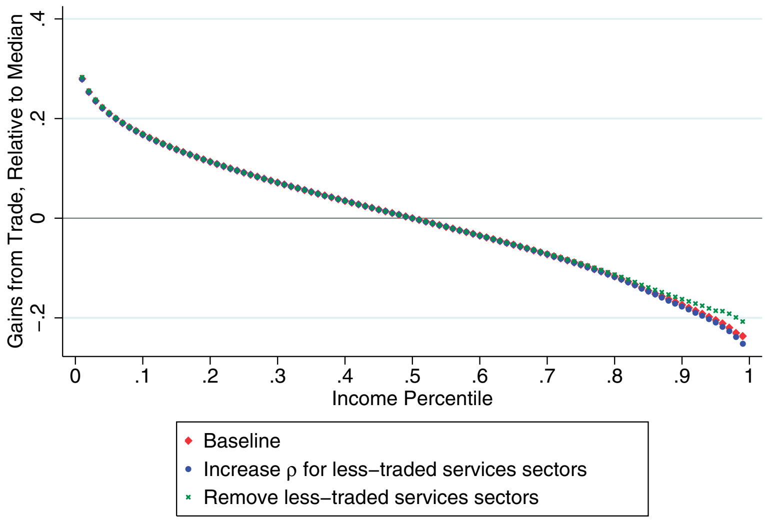

FIGURE IX

Varying Price Elasticity for Less-Traded Services

The deviations are relative to the median individual. Figure shows averages across countries, by percentile.

sectors, we lower their corresponding γ's by 20%. In a second robustness check, we treat these 12 service categories as nontradeable. Appendix B shows that equations (32) to (36) for the welfare effects of a foreign trade shock carry over exactly in the presence of nontraded sectors, the only difference being that these sectors must be excluded from the computations.

We recompute the gains from trade in these two cases and compare the results, averaged across countries, to the baseline result in Figure IX. The three curves are very similar; this reassures us that the main results are not sensitive to the value of ρ in sectors that plausibly have higher price elasticities. The high similarity across these cases is not surprising because the sectors affected by each robustness check features little trade, so that their inclusion in the baseline model does not considerably affect the computations.

telecommunications; real estate; public administration and defense; education; health; and other personal services.

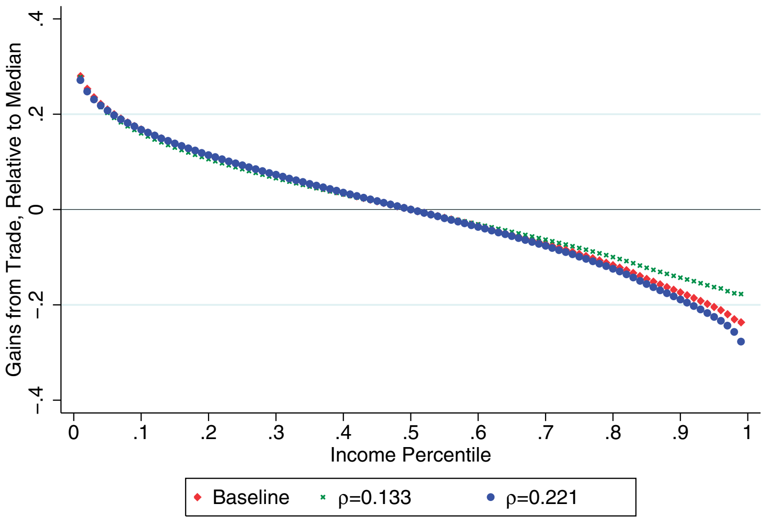

FIGURE X

Varying the Value of ρ

The deviations are relative to the median individual. Figure shows averages across countries, by percentile.

3. Additional Checks. Finally, we present additional robustness checks. As noted earlier, the parameter ρ cannot be separately identified in the data. We rerun the counterfactuals assuming a $\rho = 0.221$, or a 25% increase from the baseline value. This implies reducing of the estimate of γ, and as a result, increases the gains from trade according to equation (32). While the welfare estimates in levels increase, Figure X shows that the relative gains from trade across percentiles are largely unaffected. The figure also reports the results from setting $\rho = 0.133$, a 25% decrease in the baseline value, and again the results are qualitatively unchanged. Hence, although ρ affects the level of the gains from trade predicted by the model, it does not affect the distributional bias.[51]

Next we examine the sensitivity of our analysis by using final rather than total expenditures.[52] As mentioned earlier, the

51. When $\rho = 0.133$, the aggregate gain from trade, averaged across countries, is 25%. When $\rho = 0.221$, the average is 37%.

52. We work with total expenditures as the baseline because separating final expenditures requires taking a stand on the end use on products (see Dietzenbacher et al. 2013). The most accurate way to account for intermediate inputs would be to

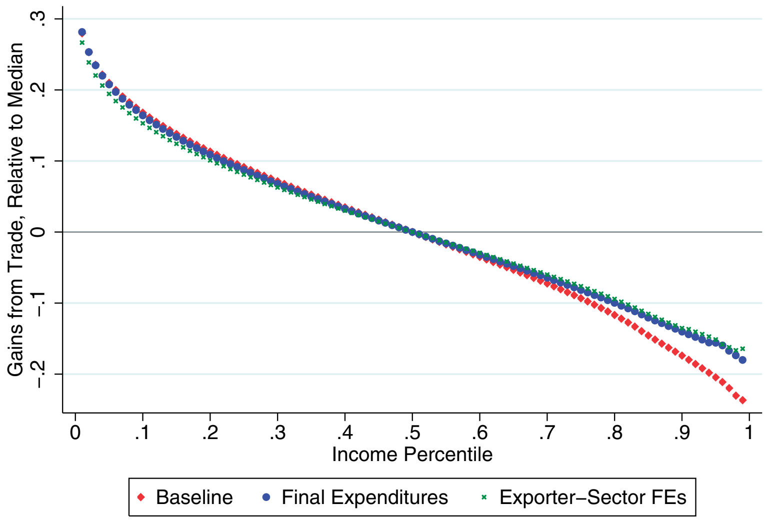

FIGURE XI

Comparing the Baseline to Final Expenditures or Exporter-Sector Fixed Effects

The deviations are relative to the median individual. Figure shows averages across countries, by percentile.

WIOD allow us to separate final expenditures from total expenditures, and we use these data to reestimate the main results. See Appendix Tables A.2 and A.3 for the parameter estimation results. Figure XI reports the welfare gains, averaged across countries, against the baseline results, and the results are similar.

The last robustness checks implements a more flexible version of the gravity equation (45) by replacing $\frac{Y_n^s}{Y_W}$ with exporter-sector pair fixed effects. This specification is more flexible in that it does not rely on the full structure of the model. We report the results of the sectoral gravity equation in Appendix Table A.4 (the Engel curve estimates of the $\overline{\beta}^s$ are the same as those reported in Table II), and find a correlation of the income elasticities with the baseline coefficients of 0.90. Figure XI compares the welfare gains with the baseline results, and once again the message remains unchanged.

enrich the supply-side structure to account for input-output linkages, but we do not pursue this route here.

V.E. Partial Changes in Trade Costs

The welfare changes implied by the trade-to-autarky counterfactual are special in two ways. First, the magnitude of the shock is larger than what is typically experienced by countries that enact trade reforms. Second, trade reforms often target specific sectors rather than all sectors at the same time; as such, the clear propoor bias of trade may not be present when a trade liberalization only affects specific sectors. In this section, we examine the welfare implications of partial reductions in trade costs involving specific sectors.

We consider a 5% reduction in the cost of importing in specific sectors: $\Delta \ln \tau_{ni}^{s} = -5\%$ for all $i \neq n$ and for all s in some subset of all sectors, and $\Delta \ln \tau_{ni}^{s} = 0$ otherwise. We separately simulate the welfare impact of this shock for each country n at a time treating each country as a small open economy, so that changes in trade costs have a negligible impact on wages in foreign countries. The change in the price of goods in sector s imported from i relative to domestically produced goods is then $\Delta \ln\left(\frac{p_{ni}^{s}}{p_{nn}^{s}}\right) = \Delta \ln \tau_{ni}^{s}$ for all i, s. Feeding these price changes to the aggregate demand system (equation (20)) we find the aggregate shares in the final scenario, and then follow the steps in Section V.A to measure welfare changes by percentile.

In results available on request, we compare the welfare change of the representative consumer implied by this shock for manufacturing sectors with the welfare changes implied by a standard multisector Armington trade model with Cobb-Douglas preferences across sectors and CES preferences across origins within sectors (e.g., Ossa 2015).[53] The aggregate gains estimates are very similar between the two models (correlation of 0.98). The 5% reduction in the cost of all manufacturing

53. In this case, the indirect utility of the representative consumer in country n is $w_n * \Pi_s^S\left(\sum \left(p_{ni}^{s}\right)^{1-\sigma^s}\right)^{\frac{-\alpha_n^s}{(1-\sigma^s)}}$, where α_n^s is the expenditure share of country n in sector s and $\sigma^s > 1$ is the elasticity of substitution across origins within sector s. The change in real income due to the partial change in trade costs in a subset of sectors $s \in shocked$ is $\prod_{s \in shocked}\left(\frac{S_{nn}^{s,trade}}{\alpha_n^s} + \sum_{i \neq n}\left(e^{(1-\sigma^s)\Delta \ln \tau_{ni}^{s}}\frac{S_{ni}^{s,trade}}{\alpha_n^s}\right)\right)^{\frac{-\alpha_n^s}{(1-\sigma^s)}} - 1$. The case of going to autarky is nested in this expression when $\Delta \ln \tau_{ni}^{s} = \infty$ for all s and $i \neq n$. We use the elasticities reported by Ossa (2015) and match them to the WIOD sector classification to compute the welfare gains.

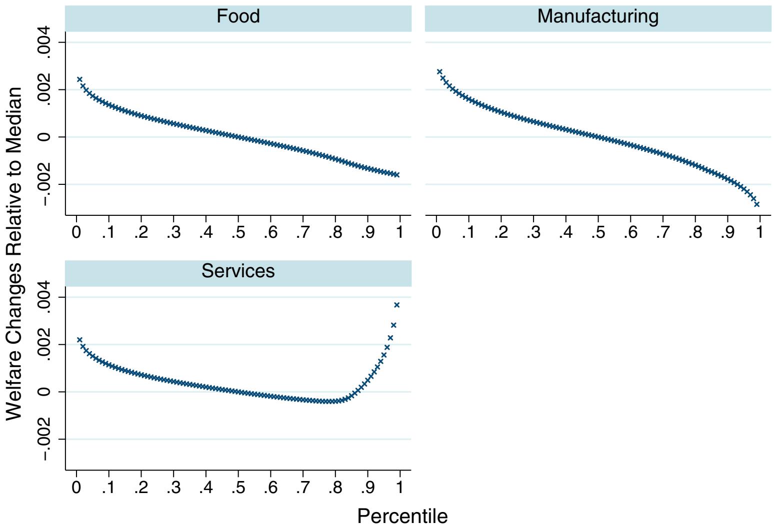

FIGURE XII

5% Reduction in Foreign Prices

Figure displays the relative welfare gaines of 5% decline in foreign trade costs for food, manufacturing, services, and all sectors.

imports increases welfare of the representative consumer by between 0.2% and 1.3% across countries.

Figure XII displays three panels that report the average welfare change across countries corresponding to the 5% trade cost decrease in the food sectors, the manufacturing sectors, and the service sectors. Given the smaller shock to prices, the differences in the gains from trade across percentiles are, of course, smaller than in the case of moving to autarky. A propoor bias of trade still results when sectors within food or manufacturing, which are typically negative-income elastic, experience a decline in foreign trade costs. Alternatively, when only the service sectors, which are typically positive-income elastic, experience a decline in the cost of importing, we see an overall U-shaped pattern, with the very rich gaining relatively more.

VI. CONCLUSION

This article develops a methodology to measure the distribution of welfare changes across heterogeneous consumers through the expenditure channel for many countries over time. The approach has broad applicability because it is based on aggregate statistics and model parameters that can be estimated from readily available bilateral trade and production data. This is possible by using the AIDS demand structure, which allows for nonhomotheticicities and has convenient aggregation properties.

We estimate a nonhomothetic gravity equation generated by the model to obtain the key parameters required by the approach, and identify the effect of trade on the distribution of welfare changes through counterfactual changes in trade costs. The estimated parameters suggest large differences in how trade affects individuals along the income distribution in different countries. The multisector analysis reveals that the gains from trade are typically biased toward the poor. This is because the poor tend to concentrate expenditures in sectors that are more traded, and because these sectors have lower price elasticities. Heterogeneity in the propoor bias of trade is driven in part by a country's pattern of specialization relative to its trading partners.

Although our goal in this article is to demonstrate the importance of demand heterogeneity across consumers for the distributional effects of trade, we believe that a promising avenue lies in integrating this approach with a richer supply-side structure to measure jointly the impact of trade through both the expenditure and income channels across consumers. We leave this for future work.

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Appendix A

This appendix provides the details to implement the counterfactuals in Section V.

Reservation Prices

The restriction to nonnegative individual expenditure shares may bind in the counterfactuals. In these cases, we find consumer-specific reservation prices that set the individual shares of dropped varieties to 0, and adjust the remaining individual shares using these reservation prices. Let $N^{s,j}_{n,h}$ be the number of varieties not consumed by percentile h from country n in sector s at prices $\{p^{s,j}_{ni}\}$ under scenario j, $I^{s,j}_{n,h}$ be the set of such varieties, and $\{p^{s,j}_{ni,h}\}$ be the reservation prices of consumer h. The notation j may correspond to the initial scenario under trade ($j=tr$) or to a counterfactual ($j=cf$).

For each percentile h in country n, we have that $p^{s,j}_{ni,h}=p^{s,j}_{ni}$ for all $i\notin I^{s,j}_{n,h}$ and $s^{s,j}_{ni,h}=0$ for all $i\in I^{s,j}_{n,h}$. From equation (23), the reservation prices $p^{s,j}_{ni,h}$ for $i\in I^{s,j}_{n,h}$ and the individual shares $s^{s,j}_{ni,h}$ for $i\notin I^{s,j}_{n,h}$ satisfy:

$$s^{s,j}_{ni,h}=\alpha^{s}_{ni}-\gamma^{s}\ln p^{s,j}_{ni}+\frac{\gamma^{s}}{N}\left(\sum_{i'\notin I^{s}_{n,h}}\ln\left(p^{s,j}_{ni'}\right)+\sum_{i'\in I^{s}_{n,h}}\ln\left(p^{s,j}_{ni',h}\right)\right)+\beta^{s}_{i}\left(\ln\left(\frac{x_h}{\tilde{x_n}}\right)+y^{j}_{n,h}\right),\ i\notin I^{s,j}_{n,h}, \tag{50}$$

$$0=\alpha^{s}_{ni}-\gamma^{s}\ln p^{s,j}_{ni,h}+\frac{\gamma^{s}}{N}\left(\sum_{i'\notin I^{s}_{n,h}}\ln\left(p^{s,j}_{ni'}\right)+\sum_{i'\in I^{s}_{n,h}}\ln\left(p^{s,j}_{ni',h}\right)\right)+\beta^{s}_{i}\left(\ln\left(\frac{x_h}{\tilde{x_n}}\right)+y^{j}_{n,h}\right),\ i\in I^{s,j}_{n,h} \tag{51}$$

for $s=1,\ldots,S$, where $y^{j}_{n,h}\equiv\ln\left(\frac{\tilde{x_n}}{a^{j}_{n,h}}\right)$ and $a^{j}_{n,h}=a\left(\left\{p^{s,j}_{ni,h}\right\}_{i,s}\right)$ is the homothetic component of the price index. Assuming that not every variety in sector s is dropped, equation (51) implies

$$\sum_{i'\in I^{s,j}_{n,h}}\gamma^{s}\ln p^{s,j}_{ni',h}=\frac{N^{s,j}_{n,h}}{N-N^{s,j}_{n,h}}\gamma^{s}\sum_{i'\notin I^{s}_{n,h}}\ln\left(p^{s,j}_{ni'}\right)+\frac{N}{N-N^{s,j}_{n,h}}\left(\sum_{i'\in I^{s,j}_{n,h}}\alpha^{s}_{ni'}+\sum_{i'\in I^{s,j}_{n,h}}\beta^{s}_{i'}\left(\ln\left(\frac{x_h}{\tilde{x_n}}\right)+y^{j}_{n,h}\right)\right). \tag{52}$$

Replacing this back into equation (51) gives the reservation prices of the dropped varieties in sector s:

$$\ln p^{s,j}_{ni,h} = \frac{1}{\gamma^s}\left[\alpha^s_{ni} + \frac{1}{N - N^{s,j}_{n,h}} \sum_{i' \in I^{s,j}_{n,h}} \alpha^s_{ni'} + \left(\beta^s_i + \frac{1}{N - N^{s,j}_{n,h}} \sum_{i' \in I^{s,j}_{n,h}} \beta^s_{i'}\right)\left(\ln\left(\frac{x_h}{\tilde{x}_n}\right) + y^j_{n,h}\right)\right] + \frac{1}{N - N^{s,j}_{n,h}} \sum_{i' \notin I^s_{n,h}} \ln\left(p^{s,j}_{ni'}\right), i \in I^{s,j}_{n,h}. \tag{53}$$

Aggregate Expenditure Shares Used in the Counterfactuals

Let $\{S^{s,j}_{ni,h}\}_{i,s}$ be the expenditure shares that result from evaluating the aggregate share equation (23) from country n at the reservation prices for consumer h under scenario j, $\{p^{s,j}_{ni,h}\}_{i,s}$.[54] In the counterfactuals, to measure welfare changes by percentile we integrate equations (32)–(36) between $\{S^{s,tr}_{ni,h}\}_{i,s}$ and $\{S^{s,cf}_{ni,h}\}_{i,s}$. To construct $\{S^{s,j}_{ni,h}\}_{i,s}$ we combine equations (22), (23), and (53) to obtain:

$$S^{s,j}_{ni,h} = \begin{cases} s^{s,j}_{ni,h} - \beta^s_i \ln\left(\frac{x_h}{\tilde{x}_n}\right), & i \notin I^{s,j}_{n,h}, \\ -\beta^s_i \ln\left(\frac{x_h}{\tilde{x}_n}\right), & i \in I^{s,j}_{n,h}. \end{cases} \tag{54}$$

Equation (54) relies on the individual shares $s^{s,j}_{ni,h}$ for $i \notin I^{s,j}_{n,h}$ defined in equation (50). We next explain how to construct these individual shares in each of the different counterfactual scenarios.

Initial Trade Scenario. For the initial trade scenario ($j = tr$) we combine equations (22) and (52) to obtain

$$s^{s,tr}_{ni,h} = \left(S^{s,tr}_{ni} + \frac{1}{N - N^{s,tr}_{n,h}} \sum_{i' \in I^{s,tr}_{n,h}} S^{s,tr}_{ni'}\right) + \left(\beta^s_i + \frac{1}{N - N^{s,tr}_{n,h}} \sum_{i' \in I^{s,tr}_{n,h}} \beta^s_{i'}\right) \times \left(\ln\left(\frac{x_h}{\tilde{x}_n}\right) + y^{tr}_{n,h} - y^{tr}_n\right), i \notin I^{s,tr}_{n,h}. \tag{55}$$

54. We note that these are neither the aggregate shares nor the shares chosen by the representative agent at prices $\{p^{s,j}_{ni,h}\}_{i,s}$. These shares result from evaluating equation (23) at the h-specific reservation prices, and they are not restricted to be between 0 and 1.

The aggregate shares $S_{ni}^{s,tr}$ are observed. The set $I_{n,h}^{s,tr}$ in equation (55) is determined by iteration: starting from $I_{n,h}^{s,tr} = \emptyset$, we compute $\{s_{ni,h}^{s,tr}\}_{i \notin I_{n,h}^{s,tr}}$ and if $s_{ni,h}^{s,tr} < 0$ we include n in the set $I_{n,h}^{s,tr}$ of the next iteration; since $y_{n,h}^{tr}$ is not observed, we approximate its value using y_n^{tr}. It can be shown that this procedure is formally equivalent to evenly redistributing the shares of varieties predicted to be negative at the actual prices among the remaining varieties within each sector.[55]

Autarky. For the counterfactuals that move consumers to autarky in Sections V.B and V.C, only own-country varieties are consumed; this implies $I_{n,h}^{s,cf} = \{i : i \neq n\}$. Equations (23) and (25) then imply:

$$s_{nn,h}^{s,cf} = \overline{\alpha}_n^s + \overline{\beta}^s \left(\ln\left(\frac{x_h}{\tilde{x}_n}\right) + y_{n,h}^{cf} \right),$$

$$s_{ni,h}^{s,cf} = 0, i \neq n. \tag{56}$$

To measure these individual autarky shares we use the values of β_i^s and $\overline{\beta}^s$ estimated in Section IV.B. From equation (24), we compute $\overline{\alpha}_n^s = S_n^s - \overline{\beta}^s y_n^{tr}$. To compute $y_{n,h}^{cf}$ we initially guess its value, then use equation (54) to compute $\{S_{ni,h}^{s,cf}\}$, and then integrate dy_n using equation (36) between $\{S_{ni}^{s,tr}\}$ and $\{S_{ni,h}^{s,cf}\}$ starting from the initial condition y_n^{tr}. These steps yield an updated value of $y_{n,h}^{cf}$, which is then used as a guess for the next iteration, and the procedure continues until convergence. This procedure achieves convergence to the same $y_{n,h}^{cf}$ from multiple initial guesses for each percentile-country pair for all but a

55. We note that these adjustments do not affect the aggregate predictions of the model: the observed aggregate expenditure shares under trade $\{S_{ni}^{s,tr}\}$ have a correlation of 0.99 with the aggregate expenditure shares $\left\{\sum_h \left(\frac{x_h}{\sum_{h'} x_{h'}}\right) s_{ni,h}^{s,tr}\right\}$ resulting from adding up the expenditures shares of each percentile h at the reservation prices $\{p_{ni,h}^{s,tr}\}$.

handful of cases which are excluded from the figures and tables referenced in Section V.[56]

Partial Changes in Trade Costs. For the counterfactuals involving partial changes in foreign trade costs (Section V.E) we construct individual shares following steps similar to the initial trade scenario using the aggregate final shares $S_{in}^{s,cf} = S_{in}^{s,tr} + \Delta S_{ni}^{s}$. The term ΔS_{ni}^{s} can be computed from equation (22), which implies

$$\Delta S_{ni}^{s} = -\gamma^{s}\left[\Delta \ln \tau_{ni}^{s} - \frac{1}{N}\sum_{i'=1}^{N}\Delta \ln \tau_{ni'}^{s}\right] + \beta_{i}^{s}\Delta y_{n}. \tag{57}$$

We integrate $dy_n = -\sum_s \sum_i \left(S_{ni}^{s} - \beta_i^s y_n\right)\hat{\tau}_{ni}^{s}$ (which follows from Shepard's lemma) and $dS_{ni}^{s} = -\gamma^{s}\left[\tau_{ni}^{\hat{s}} - \frac{1}{N}\sum_{i'=1}^{N}\tau_{ni'}^{\hat{s}}\right] + \beta_i^s dy_n$ (which follows from equation (57)) to obtain Δy_n.

Appendix: B Computing Welfare Changes with a Nontraded Sector

We derive the welfare results assuming that a subset of sectors are nontraded. Assume that $s = NT$ is a nontraded sector. We show that equations (32)–(36) for the welfare effects of a foreign trade shock remain the same with the only difference being that the nontraded sector is excluded from the expressions.

In sector $s = NT$, the preferences of country n are only defined over the variety produced by country n. We let β^{NT} be the income elasticity corresponding to the nontraded sector. The adding-up constrain then implies $\gamma^{NT} = 0$, $\beta^{NT} = -\sum_{s\neq NT}\sum_{i=1}^{N}\beta_i^s$, and $\alpha_{nn}^{NT} = \overline{\alpha}_n^{NT} = 1 - \sum_{s\neq NT}\overline{\alpha}_n^s$. Letting S_n^{NT} be the share of expenditures in nontraded goods, the aggregate expenditure shares equation (22) in country n are now defined as follows:

$$S_{ni}^{s} = \alpha_{ni}^{s} - \gamma^{s}\left[\ln\left(\frac{p_{ni}^{s}}{p_{nn}^{\hat{s}}}\right) - \frac{1}{N}\sum_{i'=1}^{N}\ln\left(\frac{p_{ni'}^{s}}{p_{nn}^{\hat{s}}}\right)\right] + \beta_i^s y_n \text{ for } s \neq NT, \tag{58}$$

$$S_n^{NT} = \overline{\alpha}_n^{NT} + \beta^{NT} y_n. \tag{59}$$

In changes, equation (58) can be written as:

56. In the baseline multisector counterfactual there are 3,960 (= 40 countries * 99 percentiles) combinations and we do not obtain convergence in 20 of these cases corresponding to extreme percentiles.

$$\hat{p}^s_{ni} - \hat{p}^s_{nn} = -\frac{dS^s_{ni} - dS^s_{nn}}{\gamma^s} + \frac{1}{\gamma^s}\left(\beta^s_i - \beta^s_n\right)dy_n. \tag{60}$$

Additionally, we have that:

$$\hat{p}^s_{nn} = \hat{p}^{NT}_{nn} = \hat{w}_n. \tag{61}$$

Since $\hat{x}_h = \hat{w}_n$, the welfare change of consumer h defined in equation (4) is:

$$\hat{\omega}_h = \hat{W}_n - \hat{b}_n \times \ln\left(\frac{x_h}{\tilde{x}}\right) + \hat{w}_n. \tag{62}$$

where, using equations (5) and (13), we have

$$\hat{W}_n = \sum_{s \neq NT} \sum_i \left(-\hat{p}^s_{ni}\right) S^s_{ni} - \hat{p}^{NT}_{nn} S^{NT}_n, \tag{63}$$

$$\hat{b}_n = \sum_{s \neq NT} \sum_i \hat{p}^s_{ni} \beta^s_i + \hat{p}^{NT}_{nn} \beta^{NT}. \tag{64}$$

Combining equations (60) to (64), and using the normalization of the own wage ($\hat{w}_n = 0$), leads to:

$$\hat{W}_n = \sum_{s \neq NT} \sum_i \left(dS^s_{ni} - dS^s_{nn} + \left(\beta^s_n - \beta^s_i\right)dy_n\right)\frac{S^s_{ni}}{\gamma^s},$$

$$\hat{b}_n = \sum_{s \neq NT} \sum_i \frac{\beta^s_i}{\gamma^s}\left(dS^s_{nn} - dS^s_{ni} + \left(\beta^s_i - \beta^s_n\right)dy_n\right),$$

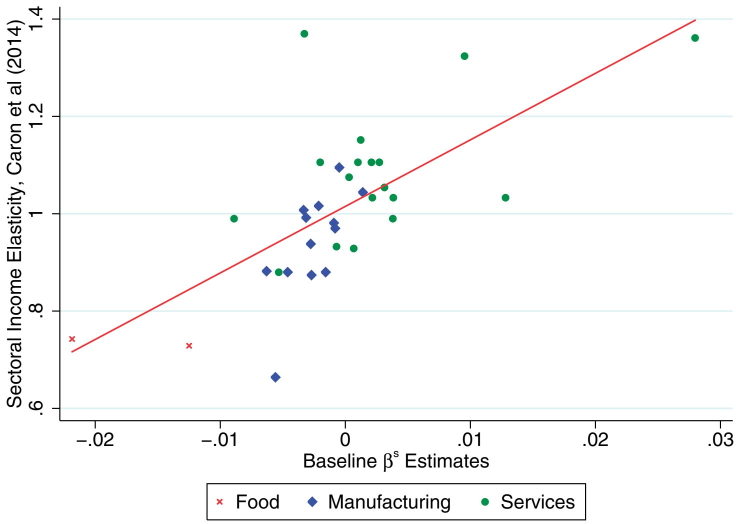
which correspond to equations (32) to (35) when all sectors are traded. To characterize welfare changes it remains to solve for dy. From Shephard's lemma,

$$\begin{aligned}\hat{a}_n &\equiv \sum_{s \neq NT} \sum_i \frac{\partial \ln a}{\partial \ln p^s_{ni}} \hat{p}^s_{ni} + \frac{\partial \ln a}{\partial \ln p^{NT}_n} \hat{p}^{NT}_n, \\ &= \sum_{s \neq NT} \sum_i \left(S^s_{ni} - \beta^s_{ni} y_n\right)\hat{p}^s_{ni} + \left(S^{NT}_n - \beta^{NT}_n y_n\right)\hat{p}^{NT}_n.\end{aligned}$$

Combining this expression with equations (60) to (64), using $dy_n = \hat{w}_n - \hat{a}_n$, and solving for dy_n yields

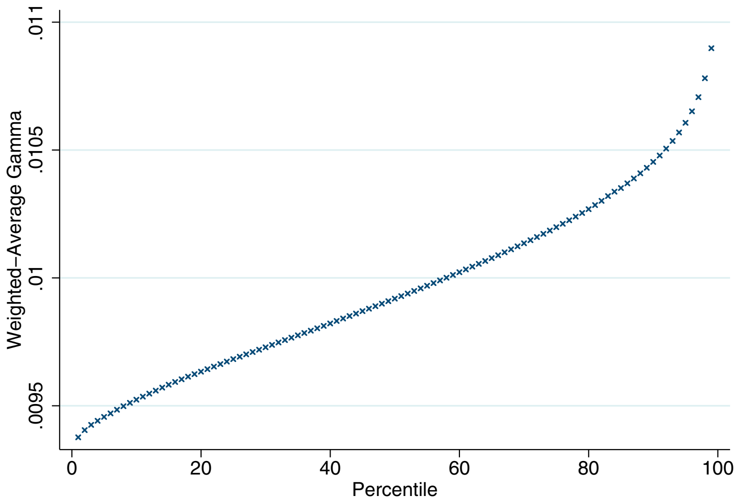
$$dy_n = \frac{\sum_{s \neq NT} \sum_i \frac{1}{\gamma^s}\left(S^s_{ni} - \beta^s_{ni} y_n\right)\left(dS^s_{ni} - dS^s_{nn}\right)}{1 - \sum_{s \neq NT} \sum_i \frac{1}{\gamma^s}\left(S^s_{ni} - \beta^s_i y_n\right)\left(\beta^s_n - \beta^s_i\right)},$$

which corresponds to equation (36) when all sectors are traded.



APPENDIX FIGURE A.1

$\overline{\beta}^s$ versus Sectoral Income Elasticities from Caron, Fally, and Markusen (2014)



APPENDIX FIGURE A.2

Average γ, by Percentile

Weighted-average gamma calculated for baseline case. The figure reports $\gamma_h^{av} = \frac{1}{N}\sum_{i=1}^{N}\sum_{s'=1}^{S} s_{n,h}^{s',adj} * \gamma^{s'}$, where $s_{n,h}^{s',adj}$ is the expenditure share of percentile h in country n on goods in sector s'.

APPENDIX TABLE A.1
MULTISECTOR TRANSLOG GRAVITY EQUATION

	(1A)	(2A)	(3A)		(1B)	(2B)	(3B)
Variables	−Distance	Language	Border		−Distance	Language	Border
Agriculture	0.0013***	0.0049***	0.0051***	Electricity, gas, and	0.0013***	0.0050***	0.0046***
	(0.000)	(0.001)	(0.001)	water supply	(0.000)	(0.001)	(0.001)
Mining	0.0006***	0.0016***	0.0023***	Construction	0.0039***	0.0131***	0.0128***
	(0.000)	(0.000)	(0.001)		(0.001)	(0.002)	(0.002)
Food, beverages,	0.0017***	0.0059***	0.0061***	Sale, repair of	0.0005***	0.0024***	0.0021***
and tobacco	(0.000)	(0.001)	(0.001)	motor vehicles	(0.000)	(0.000)	(0.000)
Textiles	0.0004***	0.0011***	0.0014***	Wholesale trade	0.0020***	0.0081***	0.0071***
	(0.000)	(0.000)	(0.000)	and commission trade	(0.000)	(0.001)	(0.001)
Leather and footwear	0.0001***	0.0002***	0.0002***	Retail trade	0.0018***	0.0059***	0.0060***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Wood products	0.0002***	0.0011***	0.0011***	Hotels and	0.0013***	0.0037***	0.0037***
	(0.000)	(0.000)	(0.000)	restaurants	(0.000)	(0.001)	(0.001)
Printing and publishing	0.0006***	0.0020***	0.0024***	Inland transport	0.0009***	0.0044***	0.0045***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Coke, refined petroleum,	0.0008***	0.0021***	0.0033***	Water transport	0.0001***	0.0002***	0.0002***
nuclear fuel	(0.000)	(0.001)	(0.001)		(0.000)	(0.000)	(0.000)
Chemicals and chemical	0.0013***	0.0016***	0.0023***	Air transport	0.0002***	0.0004***	0.0005***
products	(0.000)	(0.000)	(0.001)		(0.000)	(0.000)	(0.000)
Rubber and plastics	0.0005***	0.0010***	0.0013***	Other auxiliary	0.0004***	0.0024***	0.0023***
	(0.000)	(0.000)	(0.000)	transport activities	(0.000)	(0.000)	(0.000)
Other nonmetallic minerals	0.0005***	0.0015***	0.0016***	Post and	0.0010***	0.0033***	0.0033***
	(0.000)	(0.000)	(0.000)	telecommunications	(0.000)	(0.001)	(0.001)

APPENDIX TABLE A.1

(CONTINUED)

	(1A)	(2A)	(3A)		(1B)	(2B)	(3B)
Variables	−Distance	Language	Border		−Distance	Language	Border
Basic metals and fabricated metal	0.0017***	0.0034***	0.0045***	Financial intermediation	0.0031***	0.0056***	0.0064***
	(0.000)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
Machinery	0.0008***	0.0014***	0.0017***	Real estate activities	0.0029***	0.0097***	0.0095***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.002)	(0.002)
Electrical and optical equipment	0.0014***	0.0013***	0.0018***	Renting of M&Eq	0.0026***	0.0097***	0.0102***
	(0.000)	(0.001)	(0.000)		(0.000)	(0.002)	(0.002)
Transport equipment	0.0011***	0.0018***	0.0028***	Public admin and defense	0.0027***	0.0074***	0.0078***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.001)	(0.001)
Manufacturing, nec	0.0003***	0.0009***	0.0011***	Education	0.0012***	0.0044***	0.0039***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
				Health and social work	0.0016***	0.0061***	0.0063***
					(0.000)	(0.001)	(0.001)
				Other community and social services	0.0017***	0.0045***	0.0047***
					(0.000)	(0.001)	(0.001)
				Private households with employed persons	0.0001***	0.0002***	0.0002***
					(0.000)	(0.000)	(0.000)
		R^2		0.38			
		Observations		56,000			

Notes. Table reports the estimates of the multisector translog gravity equation, which shuts off nonhomotheticities. The results report sector-specific coefficients on (the negative of) distance, language, and border in columns (1), (2), and (3), respectively. Standard errors are clustered by importer. Significance * .10, ** .05, *** .01.

APPENDIX TABLE A.2

ENGEL CURVE ESTIMATES: FINAL EXPENDITURES

Variables	(1A)		(1B)
Agriculture	−0.0219*** (0.003)	Electricity, gas, and water supply	0.0005 (0.001)
Mining	−0.0005 (0.000)	Construction	−0.0169** (0.008)
Food, beverages, and tobacco	−0.0169*** (0.004)	Sale, repair of motor vehicles	0.0037*** (0.001)
Textiles	−0.0045*** (0.001)	Wholesale trade and commission trade	0.0009 (0.003)
Leather and footwear	−0.0009*** (0.000)	Retail trade	0.0012 (0.002)
Wood products	0.0002 (0.000)	Hotels and restaurants	0.0056** (0.002)
Printing and publishing	0.0021*** (0.000)	Inland transport	−0.0083*** (0.003)
Coke, refined petroleum, nuclear fuel	−0.0004 (0.001)	Water transport	−0.0010 (0.001)
Chemicals and chemical products	−0.0013 (0.001)	Air transport	0.0005 (0.000)
Rubber and plastics	−0.0003 (0.000)	Other auxiliary transport activities	0.0017** (0.001)
Other nonmetallic minerals	−0.0001 (0.000)	Post and telecommunications	0.0003 (0.001)
Basic metals and fabricated metal	−0.0004 (0.001)	Financial intermediation	0.0061*** (0.002)
Machinery	−0.0051* (0.003)	Real estate activities	0.0160*** (0.004)
Electrical and optical equipment	−0.0040*** (0.001)	Renting of M&Eq	0.0039** (0.002)
Transport equipment	−0.0031 (0.002)	Public admin and defense	0.0082** (0.003)
Manufacturing, nec	0.0004 (0.001)	Education	0.0044*** (0.002)
		Health and social work	0.0246*** (0.004)
		Other community and social services	0.0046 (0.003)
		Private households with employed persons	0.0008*** (0.000)
Sector FEs	yes		
Joint F-test p-value for sectoral elasticities	0.00		
R^2	0.84		
Observations	1,400		

Notes. Table reports the sectoral income elasticities from the Engel curve equation using data on final expenditures. It is a regression of importers' sectoral expenditures shares on the adjusted real income interacted with sector dummies. The regression also includes sector fixed effects. Standard errors are clustered by importer. Significance * .10, ** .05, *** .01.

APPENDIX TABLE A.3

SECTORAL GRAVITY ESTIMATES: FINAL EXPENDITURES

Variables	(1A) −Distance	(2A) Language	(3A) Border		(1B) −Distance	(2B) Language	(3B) Border
Agriculture	0.0009***	0.0044***	0.0037***	Electricity, gas, and water supply	0.0007***	0.0032***	0.0030***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.001)	(0.000)
Mining	0.0001***	0.0004**	0.0005***	Construction	0.0065***	0.0190***	0.0182***
	(0.000)	(0.000)	(0.000)		(0.001)	(0.003)	(0.004)
Food, beverages, and tobacco	0.0020***	0.0071***	0.0077***	Sale, repair of motor vehicles	0.0005***	0.0023***	0.0022***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.000)	(0.000)
Textiles	0.0003***	0.0011***	0.0015***	Wholesale trade and commission trade	0.0021***	0.0070***	0.0062***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Leather and footwear	0.0001***	0.0002***	0.0003***	Retail trade	0.0023***	0.0060***	0.0059***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Wood products	0.0001***	0.0003***	0.0003***	Hotels and restaurants	0.0019***	0.0056***	0.0060***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Printing and publishing	0.0003***	0.0009***	0.0013***	Inland transport	0.0007***	0.0036***	0.0031***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Coke, refined petroleum, nuclear fuel	0.0004***	0.0014***	0.0023***	Water transport	0.0000***	0.0002***	0.0002***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)
Chemicals and chemical products	0.0004***	0.0010***	0.0014***	Air transport	0.0002***	0.0004***	0.0004***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)
Rubber and plastics	0.0001***	0.0003***	0.0004***	Other auxiliary transport activities	0.0003***	0.0014***	0.0014***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)
Other nonmetallic minerals	0.0001**	0.0004***	0.0004***	Post and telecommunications	0.0009***	0.0024***	0.0025***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)

APPENDIX TABLE A.3

(CONTINUED)

Variables	(1A) −Distance	(2A) Language	(3A) Border		(1B) −Distance	(2B) Language	(3B) Border
Basic metals and fabricated metal	0.0004***	0.0013***	0.0011***	Financial intermediation	0.0018***	0.0049***	0.0051***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Machinery	0.0009***	0.0013***	0.0017***	Real estate activities	0.0042***	0.0132***	0.0130***
	(0.000)	(0.000)	(0.000)		(0.001)	(0.002)	(0.002)
Electrical and optical equipment	0.0008***	0.0013***	0.0016***	Renting of M&Eq	0.0010***	0.0041***	0.0040***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Transport equipment	0.0010***	0.0018***	0.0031***	Public admin and defense	0.0055***	0.0141***	0.0137***
	(0.000)	(0.001)	(0.001)		(0.001)	(0.003)	(0.003)
Manufacturing, nec	0.0004***	0.0008***	0.0013***	Education	0.0023***	0.0079***	0.0075***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
				Health and social work	0.0034***	0.0116***	0.0116***
					(0.001)	(0.002)	(0.002)
				Other community and social services	0.0025***	0.0056***	0.0061***
					(0.001)	(0.001)	(0.001)
				Private households with employed persons	0.0001**	0.0004***	0.0003***
					(0.000)	(0.000)	(0.000)
Ω_i x sector-exporter dummies			not displayed				
Joint F-test p-value for income elasticities			0.00				
R^2			0.41				
Observations			56,000				

Notes. Table reports the estimates of the sectoral gravity equation using data on final expenditures. The results report sector-specific coefficients on (the negative of) distance, language and border in columns (1), (2), and (3), respectively. The table supresses the sector-exporter interaction coefficients to save space, but recall that the sum of these coefficients across sectors equals sectoral coefficients in Appendix Table A.2. Standard errors are clustered by importer. Significance * .10, ** .05, *** .01.

APPENDIX TABLE A.4

Sectoral Gravity Estimates: Exporter-Sector Fixed Effects

	(1A)	(2A)	(3A)		(1B)	(2B)	(3B)
Variables	−Distance	Language	Border		−Distance	Language	Border
Agriculture	0.0015***	0.0065***	0.0044***	Electricity, gas, and water supply	0.0017***	0.0062***	0.0041***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.001)	(0.001)
Mining	0.0007***	0.0020***	0.0019***	Construction	0.0050***	0.0163***	0.0112***
	(0.000)	(0.001)	(0.001)		(0.001)	(0.003)	(0.003)
Food, beverages, and tobacco	0.0020***	0.0073***	0.0054***	Sale, repair of motor vehicles	0.0007***	0.0029***	0.0019***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.001)	(0.000)
Textiles	0.0004***	0.0015***	0.0012***	Wholesale trade and commission trade	0.0027***	0.0097***	0.0062***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.002)	(0.001)
Leather and footwear	0.0001***	0.0002***	0.0002***	Retail trade	0.0023***	0.0071***	0.0049***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Wood products	0.0003***	0.0013***	0.0010***	Hotels and restaurants	0.0016***	0.0044***	0.0031***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
Printing and publishing	0.0008***	0.0024***	0.0021***	Inland transport	0.0011***	0.0055***	0.0041***
	(0.000)	(0.001)	(0.000)		(0.000)	(0.001)	(0.001)
Coke, refined petroleum, nuclear fuel	0.0010***	0.0028***	0.0027***	Water transport	0.0001***	0.0003***	0.0002**
	(0.000)	(0.001)	(0.001)		(0.000)	(0.000)	(0.000)
Chemicals and chemical products	0.0014***	0.0023***	0.0017***	Air transport	0.0003***	0.0005***	0.0004***
	(0.000)	(0.001)	(0.001)		(0.000)	(0.000)	(0.000)
Rubber and plastics	0.0005***	0.0013***	0.0011***	Other auxiliary transport activities	0.0006***	0.0029***	0.0022***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.000)
Other nonmetallic minerals	0.0006***	0.0019***	0.0014***	Post and telecommunications	0.0013***	0.0040***	0.0029***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)

APPENDIX TABLE A.4

(CONTINUED)

Variables	(1A) −Distance	(2A) Language	(3A) Border		(1B) −Distance	(2B) Language	(3B) Border
Basic metals and fabricated metal	0.0021***	0.0046***	0.0037***	Financial intermediation	0.0035***	0.0072***	0.0049***
	(0.000)	(0.001)	(0.001)		(0.001)	(0.002)	(0.002)
Machinery	0.0009***	0.0018***	0.0014***	Real estate activities	0.0038***	0.0115***	0.0080***
	(0.000)	(0.000)	(0.000)		(0.001)	(0.002)	(0.002)
Electrical and optical equipment	0.0016***	0.0019***	0.0011**	Renting of M&Eq	0.0031***	0.0118***	0.0087***
	(0.000)	(0.001)	(0.000)		(0.001)	(0.003)	(0.002)
Transport equipment	0.0012***	0.0024***	0.0021***	Public admin and defence	0.0033***	0.0088***	0.0063***
	(0.000)	(0.001)	(0.001)		(0.001)	(0.002)	(0.002)
Manufacturing, nec	0.0003***	0.0010***	0.0009***	Education	0.0017***	0.0054***	0.0036***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.001)	(0.001)
				Health and social work	0.0021***	0.0073***	0.0055***
					(0.000)	(0.002)	(0.001)
				Other community and social services	0.0023***	0.0055***	0.0040***
					(0.001)	(0.001)	(0.001)
				Private households with employed persons	0.0001**	0.0002***	0.0001**
					(0.000)	(0.000)	(0.000)
Ω_i × sector-exporter dummies			not displayed				
Joint F-test p-value for income elasticities			0.00				
R^2			0.45				
Observations			56,000				

Notes. Table reports the estimates of the sectoral gravity equation that includes sector-exporter pair fixed effects. The results report sector-specific coefficients on (the negative of) distance, language and border in columns (1), (2), and (3), respectively. The table supresses the sector-exporter linteraction and level coefficients to save space, but recall that the sum of the interaction coefficients across sectors equals sectoral coefficients in Table II, and the sum of the coefficients for each exporter across sectors equals the country-specific coefficients in Table I. Standard errors are clustered by importer. Significance * .10, ** .05, *** .01.

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