

## NONHOMOTHETICITY AND BILATERAL TRADE: EVIDENCE AND A QUANTITATIVE EXPLANATION

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The standard gravity model predicts that trade flows increase in proportion to importer and exporter total income, regardless of how income is divided into income per capita and population. Bilateral trade data, however, show that trade grows strongly with income per capita and is largely unresponsive to population. I develop a general equilibrium Ricardian model of trade that allows the elasticity of trade with respect to income per capita and with respect to population to diverge. Goods are of various types, which differ in their income elasticity of demand and in the extent to which there is heterogeneity in their production technologies. I estimate the model using bilateral trade data of 162 countries and compare it to a special case that delivers the gravity equation. The general model improves the restricted model's predictions regarding variations in trade due to size and income. I experiment with counterfactuals. A positive technology shock in China makes poor and rich countries better off and middle-income countries worse off.

KEYWORDS: International trade, income per capita, gravity equation, nonhomotheticity.

### 1. INTRODUCTION

IT IS WELL KNOWN that poor countries trade much less than rich countries, both with each other and with the rest of the world. In 2000, for example, transactions to and from the twelve Western European countries alone accounted for 45% of international merchandise trade, and intra-Western European trade, for 16%. The fifty-seven African countries, in contrast, accounted for only 4.2% of world trade, and intra-African trade, a meager 0.2%. Doubling a country's income per capita *increases* trade (average between imports and exports) as a share of income by 1.7% on average, while doubling a country's population *decreases* its trade share by 2.0%. Despite these differences, standard gravity models of international trade predict that trade increases with importer and exporter total income, and ignore how total income is divided into income per capita and population.

Protectionist policies and high transport costs are the usual explanations for the small volume of trade in poor countries. But even after controlling for tariffs and direct measures of trade costs, income per capita continues to have a significant, increasing effect on trade.<sup>2</sup> Furthermore, this explanation does

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<sup>2</sup>See Coe and Hoffmaister (1999), Limão and Venables (2001), and Rodrik (1998). Waugh (2010) estimated that to explain trade shares in the data, the cost of exporting from a low-income

not take incentives into account: the low quality of infrastructure in poor countries may in part be due to these countries' lack of incentives to trade.

This paper takes an alternative view. I purposely abstract from differences in trade costs across countries and focus on two assumptions of gravity models that are inconsistent with microlevel evidence. The first is homothetic preferences. There is exhaustive evidence that the income elasticity of demand varies across goods and that this variation is economically significant.<sup>3</sup> For example, spending on food, a low income-elastic good, ranged from 64% in Tanzania to less than 15% in Australia and North America in the early 1980s (Grigg (1994)). The second assumption is that production in poor and rich countries differs only in quantitative, not qualitative, aspects. This assumption is at odds with the theory of product cycle and with empirical evidence on technology diffusion.<sup>4</sup> When a good is first invented, the argument goes, the technology to produce it differs greatly across countries, most of which do not know how to make it. At this stage, the good is generally produced in the typically high-income country where it was invented. As the product matures, methods to produce it become standardized and can be applied similarly to any country, including those where labor is cheap. So, in a cross section, poor countries should produce disproportionately more goods whose technologies have already diffused and are similar across countries.

I propose an analytically tractable Ricardian model of trade that relaxes these two assumptions. Goods in the model are divided into types, which may differ in two respects: demand and technology. Poor households concentrate their spending on types with low income elasticity, and rich ones, on types with high income elasticity. The supply side setup is Ricardian: labor is the unique factor of production; markets are perfectly competitive, and comparative advantage arises from differences in technologies across goods and countries. The distribution of labor efficiency may be more variable for some types of goods than for others. Analogous to the product cycle theory, in general equilibrium, countries where overall productivity is low have low wages and produce less differentiated goods. Technologically advanced countries have high wages and produce goods whose technologies are more variable across countries.

If there is only one type of good, the model reduces to Eaton and Kortum (2002; EK henceforth) and delivers the gravity equation. This special case thus

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country would need to be approximately 4.5 times higher than the cost of exporting from the United States (Figure 2 in his paper). See also Markusen and Wigle (1990), who estimated the effect of trade barriers on trade across countries of different income levels, and Hunter and Markusen (1988), who estimated the effect of nonhomothetic preferences.

<sup>3</sup>See Bilal and Klenow (1998), Deaton (1975), Grigg (1994), and Hunter (1991).

<sup>4</sup>See Comin and Hobijn (2006), Nabseth and Ray (1974), Romer (1990), and Vernon (1966).

delivers the same patterns of trade as other gravity models, and it predicts the same elasticity of trade with respect to income per capita and to population.<sup>5</sup>

I estimate the model with one type (EK model) and with two types of goods, using data on bilateral merchandise trade flows in 2000. I use two data sets—one containing 162 countries and the other containing a subset of 19 Organization for Economic Cooperation and Development (OECD) countries. The data report the total value of trade for each importer–exporter country pair. The EK model explains trade in the OECD sample very well, but not trade in the full sample with countries of different size and income levels. The new model, in turn, explains trade among OECD countries as well as EK and significantly improves upon EK in explaining the full sample. The estimated parameters of the model are such that production technologies are more variable in the type of good whose demand is more income-elastic. Hence, rich countries consume and produce these goods more intensively. And the variability in their production technologies generates large price dispersions, which give rich countries large incentives to trade. Poor countries, in contrast, produce and consume relatively more goods whose technologies are similar across countries. As a result, they trade little.

So, the new model simultaneously explains the large volume of trade among rich countries and the small volume among poor countries, patterns that cannot be reconciled with the EK model. For example, trade among the 20 richest countries in the sample accounts on average for 27% of these countries' incomes. Similarly, the new model predicts this trade to be 16% of income, while the EK model predicts that it is only 2%. Trade among the 20 poorest countries, in turn, is less than 2% of these countries' incomes according to the data, and the new and the EK model.

Trade deficits with rich countries are larger for middle- than for low-income countries in the data. To capture this moment, the estimated parameters imply that as a country's income per capita grows, its demand for goods with high income elasticity increases before its supply. So, middle-income countries are net importers of these goods, rich countries are net exporters, and poor countries barely consume or produce them.

Counterfactual simulations illustrate the welfare consequences of this pattern. A positive technology shock in China makes poor and rich countries better off and middle-income countries worse off. The shock shifts Chinese demand toward high income-elastic goods, while maintaining China's specialization in low income-elastic goods. Two price changes ensue. First, the price of low elasticity goods (Chinese exports) decreases relative to wages in most countries, a change that benefits primarily poor countries, the largest consumers of low elasticity goods. Second, the price of high elasticity goods (Chinese imports) increases relative to low elasticity goods. This price change benefits net exporters of high elasticity goods—rich countries—and it hurts net

<sup>5</sup>See Anderson and Van Wincoop (2003), Helpman and Krugman (1985), Redding and Venables (2004).

importers—middle-income countries. A technology shock in the United States, a rich country, has the opposite effect of the shock in China.

I extend the model to admit income inequalities within countries and intermediate inputs. With intermediate inputs, rich countries may absorb relatively more goods with heterogeneous technologies for two reasons: these goods have high income elasticity of demand (as before) and their production requires relatively more inputs themselves with heterogeneous technologies. Data on trade flows do not distinguish between these two possibilities. In an additional exercise, I estimate the model with importer fixed effects in lieu of structural assumptions on preferences. Supply side parameters do not change much with this specification, and again I find that rich countries consume relatively more goods with heterogeneous technologies.<sup>6</sup>

This paper relates to several other strands of literature. Linder (1961) also proposed a theory of trade where trade flows are determined by demand patterns, through nonhomothetic preferences. The proximity to a large consumer market for high-quality goods, Linder argued, gives firms in rich countries a comparative advantage in developing and producing these goods. Additionally, when exporting, these firms find more extensive markets for their high-quality goods in other rich countries. Applying this same rationale to other income levels, Linder predicted that trade volumes are larger across countries with similar income levels. The new model also predicts that countries of similar income levels consume and produce the same types of goods: rich countries, high income-elastic goods; and poor countries, low income-elastic goods. In contrast to Linder, however, trade volumes depend on how differentiated products are. With the estimated parameters, rich countries trade a lot with each other because high income-elastic goods are more differentiated, while poor countries do not trade much because low income-elastic goods are less differentiated.

At the microlevel, recent studies found that unit prices within commodity categories increase systematically with importer and exporter per capita income.<sup>7</sup> If prices reflect quality differences, these findings suggest that high-income countries import and export higher quality goods—just as Linder predicted. But these findings are not easily mapped to the new model, where goods are not differentiated by quality levels.<sup>8</sup>

<sup>6</sup>I thank one of the anonymous referees for suggesting the fixed-effects estimator.

<sup>7</sup>See Choi, Hummels, and Xiang (2009), Fieler (2011a), Hummels and Klenow (2005), and Schott (2004). Empirical support for the Linder hypothesis in aggregate trade flows is mixed. See, for example, Bergstrand (1990), Hallak (2010), and Leamer and Levinsohn (1995).

<sup>8</sup>In principle, one could interpret the high income-elastic goods in the model as high-quality goods and the low income-elastic goods as low-quality. But here, as consumers get richer, the consumption of all goods increases in absolute terms, and only the relative consumption of low income-elastic goods decreases. With quality differentiation, it is more natural to assume that the absolute consumption of low-quality goods decreases with wealth, as consumers substitute these goods for higher quality ones.

Previous models of trade with nonhomothetic preferences are highly stylized.<sup>9</sup> In contrast to these models, the new model allows one to simultaneously analyze all directions of trade—North–North, North–South, and South–South—and to analyze data.

I also introduce a new method for estimating the EK model.<sup>10</sup> The usual regression approach is not applicable to the new model because of nonlinearities in the expression for trade flows. The new method explores the general equilibrium feature of the model and avoids some of the endogeneity problems of regression analysis (see Section 3). Its application extends EK to a larger data set—EK used only data on trade in manufactures among 19 OECD countries.

The paper is organized as follows. I present the theory in Section 2 and the empirical analysis in Section 3. Section 4 exploits counterfactuals. Section 5 extends the model to include income inequalities within countries and intermediate inputs. Section 6 concludes. The Appendix in the Supplemental Material (Fieler (2011b)) generalizes the demand side setup of the model, and presents details of the data, robustness checks, and Monte Carlo simulations.

## 2. THEORY

I present the model in Sections 2.1 and 2.2, solve it in Section 2.3, and explain its workings in Section 2.4. Section 2.5 shows that the EK model is a special case of the new model.

### 2.1. *The Environment*

There are  $N$  countries, and goods are divided into  $S$  types, each with a continuum of goods. Goods of type  $\tau \in \{1, 2, \dots, S\}$  are denoted by  $j_\tau \in [0, 1]$ . All consumers in the world choose the quantities of goods  $j_\tau$ ,  $\{q(j_\tau)\}_{j_\tau \in [0, 1]}$ , to maximize the same utility function,

$$(1) \quad \sum_{\tau=1}^S \left\{ (\alpha_\tau)^{1/\sigma_\tau} \left( \frac{\sigma_\tau}{\sigma_\tau - 1} \right) \int_0^1 [q(j_\tau)]^{(\sigma_\tau - 1)/\sigma_\tau} dj_\tau \right\},$$

where  $\alpha_\tau > 0$  are weights and  $\sigma_\tau > 1$  for all  $\tau$ . I normalize  $\sum_{\tau=1}^S (\alpha_\tau)^{1/\sigma_\tau} = 1$ .

Parameter  $\sigma_\tau$  is typically associated with its role as the elasticity of substitution, but here it also governs the income elasticity of demand. To see this, consider any two types of goods,  $\tau = 1, 2$ , and let  $x_\tau$  be the total spending on

<sup>9</sup>See Flam and Helpman (1987), Markusen (1986), Matsuyama (2000), and Stokey (1991).

<sup>10</sup>For other methods, see Alvarez and Lucas (2007), Eaton and Kortum (2002), and Waugh (2010).

goods of type  $\tau$ . Then, from the first-order conditions, spending on type 1 relative to type 2 satisfies

$$(2) \quad \frac{x_1}{x_2} = \lambda^{\sigma_2 - \sigma_1} \left( \frac{\alpha_1 P_1^{1 - \sigma_1}}{\alpha_2 P_2^{1 - \sigma_2}} \right),$$

where  $P_\tau$  is the constant elasticity of substitution (CES) price index of goods of type  $\tau = 1, 2$  and  $\lambda > 0$  is the Lagrange multiplier associated with the consumer's problem. It is strictly decreasing in the consumer's total income.

The term in parentheses governs the level of  $x_1/x_2$ . It increases with  $\alpha_1$  and decreases with  $P_1$ . The term  $(\lambda^{\sigma_2 - \sigma_1})$ , in turn, governs how  $x_1/x_2$  changes with consumer income. If  $\sigma_1 > \sigma_2$ , the ratio  $x_1/x_2$  is decreasing in  $\lambda$  and hence increasing in income. At all levels of income and prices, the income elasticity of demand for type 1 goods relative to the elasticity for type 2 equals  $\frac{\sigma_1}{\sigma_2}$ .<sup>11</sup> So, utility function (1) allows for consumers of different income levels to concentrate their spending on different types of goods.

Parameter  $\sigma_\tau$  governs both the elasticity of substitution across goods of the same type and the income elasticity of demand for those goods. Nothing in the results, however, depends on the elasticity of substitution. Demand affects trade only through the allocation of spending across types because, within types, the share of each exporter in a country's imports does not depend on the elasticity of substitution, only on technologies.<sup>12</sup> Accordingly, throughout the paper, the only relevance of  $\sigma_\tau$  is as the income elasticity of demand. (See also Appendix A for a more general utility function.)

## 2.2. Technologies

Labor, the unique factor of production, is perfectly mobile across types and goods, and it is immobile across countries.<sup>13</sup> Technologies vary across goods and countries. Let  $z_i(j_\tau)$  be the efficiency of labor to produce good  $j_\tau$  in country  $i$ . Assuming constant returns to scale, the unit cost of producing good  $j_\tau$  in country  $i$  is  $\frac{w_i}{z_i(j_\tau)}$ , where  $w_i$  is the wage in country  $i$ .

Trade is subject to iceberg costs. Delivering one unit of good  $j_\tau$  from country  $i$  to country  $n$  requires the production of  $d_{ni}$  units. Hence, its total cost is

$$p_{ni}(j_\tau) = \frac{d_{ni} w_i}{z_i(j_\tau)}.$$

<sup>11</sup>The income elasticity of demand of type  $\tau$  is  $\frac{w}{x_\tau} \frac{dx_\tau}{dw} = (-\sigma_\tau w \frac{d\lambda}{dw})$ , where  $w$  is the consumer income.

<sup>12</sup>This result extends from Eaton and Kortum (2002), where there is only one type and  $\sigma$  does not enter the expression of trade flows.

<sup>13</sup>Labor can be interpreted more generally in the theoretical model as an input bundle, including capital. I use the term labor throughout, however, because that is the interpretation used in the empirical analysis of Section 3 below.

I normalize  $d_{ii} = 1$  for all  $i$  and assume the triangle inequality,  $d_{ni} \leq d_{nk}d_{ki}$  for all  $i, k,$  and  $n$ . With perfect competition, the price of good  $j_\tau$  faced by consumers in country  $n$  is

$$p_n(j_\tau) = \min\{p_{ni}(j_\tau) : i = 1, \dots, N\}.$$

Following EK, I employ a probabilistic representation of technologies to derive the distribution of prices. For any  $z \geq 0$ , the measure of the set of goods  $j_\tau \in [0, 1]$  such that  $z_i(j_\tau) \leq z$  is equal to the cumulative distribution function of a Fréchet random variable,

$$(3) \quad F_{i\tau}(z) = \exp(-T_i z^{-\theta_\tau}),$$

where  $T_i > 0$  for all countries  $i = 1, \dots, N$ , and  $\theta_\tau > 1$  for all types  $\tau = 1, \dots, S$ . These distributions are treated as independent across countries and types.

Figure 1 shows four densities of Fréchet distributions. Given  $\theta_\tau$ , the country-specific parameter  $T_i$  determines the level of the distribution: a larger  $T_i$  increases the measure of goods with large, efficient technologies  $z_i(j_\tau)$ . Thus, the assumption that  $T_i$  does not depend on type  $\tau$ , made just for parsimony, implies that a country that is generally efficient at making goods of one type is also efficient at making goods of other types.

Parameters  $\theta_\tau$  are common to all countries but may differ across types. These parameters govern the spread of the distribution: the larger the  $\theta_\tau$ , the smaller the variability in labor efficiencies across *goods* and *countries*. In Figure 1, the

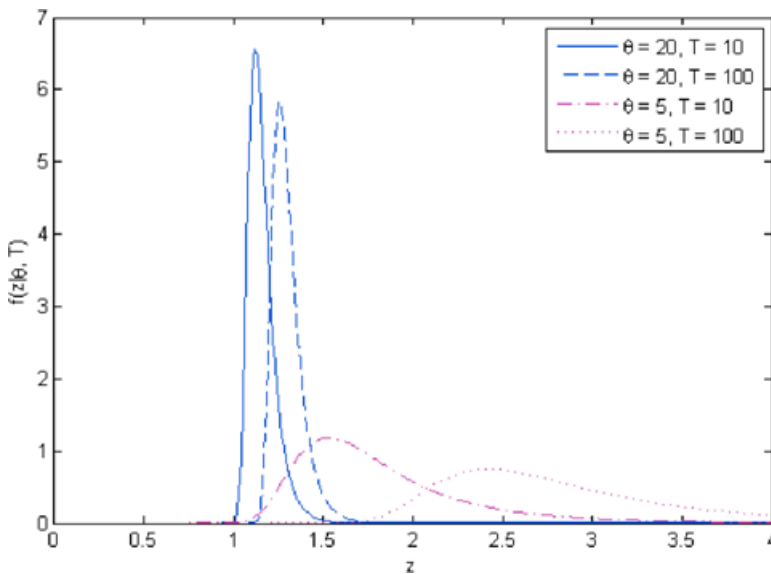


FIGURE 1.—Examples of Fréchet distributions.

decrease in  $\theta$  from 20 to 5 increases the dispersion of the distribution of technologies across goods for a fixed  $T$ . And, importantly, it increases the dispersion of technologies across countries: it shifts the density with  $T = 100$  away from the density with  $T = 10$ .

This property of the Fréchet distribution gives a dual role to parameters  $\theta_\tau$  in the model. First, the variability of technologies across *goods* governs comparative advantage *within* types. A greater dispersion in labor efficiencies (a smaller  $\theta_\tau$ ) generates a greater price dispersion and, consequently, a greater volume of trade. Trade is more intense in types where  $\theta_\tau$  is small.

Second, the variability of labor efficiencies across *countries* governs comparative advantage *across* types. The mean of the Fréchet distribution helps illustrate this point. The cost of delivering one unit of good  $j_\tau$  from country  $i$  to country  $n$  relative to the cost of producing it domestically is  $\frac{p_{ni}(j_\tau)}{p_{nn}(j_\tau)} = \frac{z_n(j_\tau)}{z_i(j_\tau)} \frac{d_{ni}w_i}{w_n}$ . Taking the expectation over  $j_\tau$ , we get

$$(4) \quad \frac{E(p_{ni}(j_\tau))}{E(p_{nn}(j_\tau))} = \left(\frac{T_i}{T_n}\right)^{-1/\theta_\tau} \frac{d_{ni}w_i}{w_n}.$$

Two factors control the cost of producing goods in country  $i$  relative to producing them in country  $n$ : the ratio of their effective wages ( $\frac{d_{ni}w_i}{w_n}$ ) and the ratio of technology parameters ( $\frac{T_i}{T_n}$ ). Parameter  $\theta_\tau$  controls the relative importance of these two factors. As  $\theta_\tau$  increases, the term  $(\frac{T_i}{T_n})^{-1/\theta_\tau}$  approaches 1 and effective wages swamp technology in determining costs. Poor countries tend to specialize in types where  $\theta_\tau$  is large because they have low wages. Rich countries, in turn, specialize in types where  $\theta_\tau$  is small because, in general equilibrium, these are the countries with large labor efficiencies, that is, large  $T_i$ 's.

Although the model is static, this production setup can be seen as arising from a product cycle if parameter  $\theta_\tau$  is interpreted as the age of goods of type  $\tau$ . When  $\theta_\tau$  is small, goods of type  $\tau$  have just been invented and methods to produce them vary greatly across countries. A good at this stage is produced in the typically high income country where it was invented. As  $\theta_\tau$  increases, methods to produce goods of type  $\tau$  become standardized (less variable across countries) and production shifts to countries with low labor costs.

### 2.3. Equilibrium

Following the literature, I do not distinguish between population and labor force. All countries have a continuum of individuals who supply inelastically one unit of labor. Let  $L_i$  be the population of country  $i$ . Assume that  $(\theta_\tau + 1) > \sigma_\tau$  for all  $\tau = 1, \dots, S$ , the well known necessary condition for a finite solution (see Eaton and Kortum (2002)). I denote the spending of an individual with small  $x$  and the spending of countries with capital  $X$ , and where needed, I use subscripts to specify type ( $\tau$ ), importer ( $n$ ), and exporter ( $i$ ).

Given wages  $w_i$  and trade costs  $d_{ni}$ , the distribution of technologies yields the distribution of prices, which, together with the utility function, yields the demand function.

The spending of a typical consumer in country  $n$  on goods of type  $\tau$  is

$$(5) \quad x_{n\tau} = \lambda_n^{-\sigma_\tau} \alpha_\tau P_{n\tau}^{1-\sigma_\tau},$$

where  $\lambda_n > 0$  is the Lagrange multiplier associated with the consumer's problem. It is implicitly defined through the budget constraint,  $\sum_{\tau=1}^S x_{n\tau} = w_n$ , as a continuous and strictly decreasing function of income  $w_n$ . The CES price index is the same as in EK,  $P_{n\tau} = [\Gamma(\frac{\theta_\tau+1-\sigma_\tau}{\theta_\tau})]^{1/(1-\sigma_\tau)} (\Phi_{n\tau})^{-1/\theta_\tau}$ , where  $\Gamma$  is the gamma function and  $\Phi_{n\tau} = \sum_{i=1}^N T_i (d_{ni} w_i)^{-\theta_\tau}$ .

The spending of a consumer in country  $n$  on goods of type  $\tau$  from country  $i$  is

$$(6) \quad x_{ni\tau} = \frac{T_i (d_{ni} w_i)^{-\theta_\tau}}{\Phi_{n\tau}} x_{n\tau}.$$

Country  $n$ 's imports from country  $i$  total

$$(7) \quad X_{ni} = L_n \left( \sum_{\tau=1}^S x_{ni\tau} \right).$$

By equating supply to demand, we get the labor market clearing conditions:

$$(8) \quad L_i w_i = \sum_{n=1}^N X_{ni} \quad \text{for } i = 1, \dots, N.$$

This completes the statement of the model. To summarize, an economy is defined by a set of  $N$  countries, each with its population  $L_i$ , technology parameter  $T_i$ , and location implied by trade barriers  $\{d_{ni}\}_{n,i \leq N}$ , and by a set of  $S$  types, each with its technology parameter  $\theta_\tau$  and preference parameters  $\alpha_\tau$  and  $\sigma_\tau$ . Given wages  $w$ , the matrix of trade flows  $\{X_{ni}\}_{n,i \leq N}$  is given by equations (5)–(7). An equilibrium is a set of wages  $w \in \Delta(N - 1)$  that satisfies the market clearing condition (8).

#### 2.4. Income per capita and Trade Patterns

This section explains how income per capita affects trade in the model. Consider the case with two types of goods,  $A$  and  $B$ , as in the empirical analysis of Section 3 below. If preferences were homothetic, the distribution of in-

come across goods would be independent of income levels. But by equation (5), country  $n$ 's demand satisfies

$$(9) \quad \frac{X_{nA}}{X_{nB}} = (\lambda_n)^{\sigma_B - \sigma_A} \left( \frac{\alpha_A P_{nA}^{1-\sigma_A}}{\alpha_B P_{nB}^{1-\sigma_B}} \right),$$

which is the same as equation (2). Assuming  $\sigma_A > \sigma_B$ , the relative spending on goods of type  $A$ ,  $\frac{X_{nA}}{X_{nB}}$ , is decreasing in  $\lambda$  and increasing in wealth.

Ultimately, however, we are interested in how this ratio affects trade. Let  $X_{ni\tau}$  be country  $n$ 's spending on goods of type  $\tau$  from country  $i$ . From equation (9), country  $n$ 's imports from country  $i$  relative to its domestic consumption,  $\frac{X_{ni}}{X_{nn}}$ , is mostly determined by  $\frac{X_{niA}}{X_{nnA}}$  if country  $n$  is rich and by  $\frac{X_{niB}}{X_{nnB}}$  if it is poor. By equation (6),

$$\frac{X_{niA}}{X_{nnA}} = \frac{T_i}{T_n} \left( \frac{d_{ni}w_i}{w_n} \right)^{-\theta_A} \quad \text{and} \quad \frac{X_{niB}}{X_{nnB}} = \frac{T_i}{T_n} \left( \frac{d_{ni}w_i}{w_n} \right)^{-\theta_B}.$$

These are the expressions on the right-hand side of equation (4), raised to the power  $(-\theta_\tau)$ , so the conclusions drawn there follow: If  $\theta_\tau$  is large, the variability in production technologies across goods and countries is small, and consumers place more emphasis on the effective cost of labor  $(\frac{d_{ni}w_i}{w_n})$  than on technology parameters  $(\frac{T_i}{T_n})$ .

To make this point clearer, suppose that  $\theta_A < \theta_B$ , as in the empirical results below, and that country  $n$  is poor. Then  $(\frac{d_{ni}w_i}{w_n}) > 1$  in general because  $w_n$  is small and  $d_{ni} > 1$ . Hence,  $(\frac{d_{ni}w_i}{w_n})^{-\theta_B}$  is close to zero because  $\theta_B$  is large. Country  $n$ 's imports are then small,  $\frac{X_{ni}}{X_{nn}} \approx \frac{X_{niB}}{X_{nnB}} = \frac{T_i}{T_n} (\frac{d_{ni}w_i}{w_n})^{-\theta_B} \approx 0$ . In words, poor countries have few incentives to trade because they consume goods whose technologies are similar across countries. Their lowest cost is typically attained domestically, with cheap labor and no trade costs.

The scenario changes if country  $n$  is rich and  $\frac{X_{ni}}{X_{nn}} \approx \frac{X_{niA}}{X_{nnA}}$ . Since  $\theta_A$  is small, the term  $(\frac{d_{ni}w_i}{w_n})^{-\theta_A}$  is relatively close to 1 irrespective of whether  $(\frac{d_{ni}w_i}{w_n})$  is smaller or greater than 1. Then  $\frac{X_{niA}}{X_{nnA}}$  is largely determined by the ratio  $\frac{T_i}{T_n}$ . Two effects follow. First, rich countries trade more than poor countries because their consumers put less emphasis on trade barriers and wages  $(d_{ni}w_i)$ . Second, they trade more with other rich countries, whose technology parameters  $T_i$  are large. In accordance with the empirical evidence mentioned in the [Introduction](#), the model predicts trade to be more intense among rich countries whenever  $\sigma_A > \sigma_B$  and  $\theta_A < \theta_B$ .

2.5. *A Special Case: The Eaton–Kortum Gravity Model*

The new model reduces to the EK model under two special cases. The easiest case arises when there is only one type of good:  $\alpha_\tau = 1$  for some  $\tau$ . Production efficiencies are distributed as per EK (equation (3)) and the utility function becomes

$$\frac{\sigma_\tau}{\sigma_\tau - 1} \int_0^1 [q(j_\tau)^{(\sigma_\tau - 1)/\sigma_\tau}] dj_\tau,$$

which represents standard homothetic CES preferences. Country  $n$ 's imports from country  $i$  are then

$$(10) \quad X_{ni} = X_{ni\tau} = \frac{T_i(d_{ni}w_i)^{-\theta_\tau}}{\Phi_{n\tau}} X_n,$$

where  $X_n = w_n L_n$  is country  $n$ 's total income. This is the solution to the EK model.<sup>14</sup> Trade flows depend on total income and not on its division into income per capita and population.

The second case arises when  $\theta_\tau = \theta$  for all  $\tau = 1, \dots, S$ . Then the share of country  $i$  in country  $n$ 's consumption of type  $\tau$  is

$$\frac{X_{ni\tau}}{X_{n\tau}} = \frac{T_i(w_i d_{ni})^{-\theta}}{\sum_{k=1}^N T_k(w_k d_{nk})^{-\theta}},$$

which does not depend on type  $\tau$ . Hence, the share of country  $i$  in country  $n$ 's total consumption is the same,  $\frac{X_{ni}}{X_n} = \frac{T_i(w_i d_{ni})^{-\theta}}{\sum_{k=1}^N T_k(w_k d_{nk})^{-\theta}}$ , as in equation (10).

This last case shows that nonhomothetic preferences alone do not modify trade flows. Consumers of different income levels may demand different types of goods, but if the distribution of technologies is equal across types, they source goods from the same countries. The converse is not true. If  $\sigma_\tau = \sigma$  for all  $\tau$ , preferences are homothetic, but technologies may differ across types. Although I do not present the results, I estimate the model with this restriction and find the  $R^2$  to be about two-thirds closer to the unrestricted model than to the EK model. (Section 3.1.2 below discusses separately the effect of each parameter on trade.)

3. EMPIRICAL ANALYSIS

I use data on bilateral merchandise trade flows in 2000 from the U.N. Comtrade data base (United Nations (2008)), and data on population and income

<sup>14</sup>Eaton and Kortum (2002) considered only trade in manufactured products. So instead of country  $n$ 's total income,  $X_n$ , they have its manufacturing absorption.

from the World Bank (2008). The data comprise 162 countries and account for 95% of world trade in 2000. There are 25,810 observations, each containing the total value of trade for an importer–exporter country pair. The list of countries and the details of the data and their compilation are supplied in Appendix B. Data specific to country pairs—distance between their most populated cities, common official language, and borders—are compiled by Mayer and Zignago (2006).

The objective of this section is to evaluate qualitatively and quantitatively the ability of the model to explain bilateral trade flows. I consider only the special case with two types of goods, denoted by  $A$  and  $B$ , and I use two empirical specifications<sup>15</sup>: the first is more efficient—it recovers simultaneously all parameters from the demand and the supply sides. The second uses importer fixed effects—it is more robust because it recovers the supply side parameters without putting structure into demand; demand parameters are estimated in a subsequent step. The first empirical specification is given in Section 3.1 and the second is given in Section 3.2.

### 3.1. Empirical Specification 1: Restricted Model

I present the estimation procedure in Section 3.1.1, identification issues in Section 3.1.2, and results in Section 3.1.3.

#### 3.1.1. Empirical Specification 1: Procedure

Equations (5), (6), and (7) above imply that country  $n$ 's imports from country  $i$  equal

$$(11) \quad X_{ni} = L_n(x_{niA} + x_{niB}),$$

where, for  $\tau = A, B$ ,

$$\begin{aligned} x_{ni\tau} &= \frac{T_i(d_{ni}w_i)^{-\theta_\tau}}{\Phi_{n\tau}} x_{n\tau}, \\ x_{n\tau} &= (\lambda_n)^{-\sigma_\tau} \alpha_\tau P_{n\tau}^{1-\sigma_\tau}, \\ \Phi_{n\tau} &= \sum_{i=1}^N T_i(d_{ni}w_i)^{-\theta_\tau}, \\ P_{n\tau} &= \left[ \Gamma\left(\frac{\theta_\tau + 1 - \sigma_\tau}{\theta_\tau}\right) \right]^{1/(1-\sigma_\tau)} (\Phi_{n\tau})^{-1/\theta_\tau}, \end{aligned}$$

<sup>15</sup>As a robustness check, I also estimate the model with three and with four types. In both cases, the trade flows predicted by the model do not change at all with respect to the two-type case, and the type-specific parameters  $\alpha_\tau$  and  $\theta_\tau$  are not identified.

$(\alpha_A)^{1/\sigma_A} + (\alpha_B)^{1/\sigma_B} = 1$ , and the Lagrange multiplier  $\lambda_n$  is implicitly defined through the budget constraint of a typical consumer in country  $n$ ,  $x_{nA} + x_{nB} = w_n$ .

Trade flows are a function of the set of  $N$  countries, each with its population  $L_i$ , wage  $w_i$ , technology parameter  $T_i$  and trade costs  $d_{ni}$ ; parameters  $\theta_A$  and  $\theta_B$  that control the spread of the distribution of technologies; utility parameters  $\sigma_A$  and  $\sigma_B$  that control the income elasticity of demand; and the weight of type  $A$  goods in preferences  $\alpha_A$ . I take the set of countries, their population  $L_i$ , and wages  $w_i$  from the data, and I estimate  $\{d_{ni}\}_{n,i=1}^N$ ,  $\{T_i\}_{i=1}^N$ ,  $\theta_A$ ,  $\theta_B$ ,  $\alpha_A$ ,  $\sigma_A$ , and  $\sigma_B$ .

*Trade Barriers  $d_{ni}$ .* Assume that trade costs take the form

$$(12) \quad d_{ni} = 1 + \{(\gamma_1 + \gamma_2 D_{ni} + \gamma_3 D_{ni}^2) * \gamma_{\text{border}} * \gamma_{\text{language}} * \gamma_{\text{trade agreement}}\}$$

for all  $n \neq i$ , and  $d_{nn} = 1$ . The term in brackets is the proxy for geographic barriers, and the number 1 added to it is the production cost. Variable  $D_{ni}$  is the distance (in thousands of kilometers) between countries  $n$  and  $i$ . So the term in parentheses is the effect of distance on trade costs. Parameter  $\gamma_{\text{border}}$  equals 1 if countries  $n$  and  $i$  do not share a border, and it is a parameter to be estimated otherwise. If  $\gamma_{\text{border}}$  is, say, 0.8, sharing a border reduces trade costs by 20%, but it does not affect production costs; if  $\gamma_{\text{border}} > 1$ , sharing a border increases trade costs. Similarly, parameters  $\gamma_{\text{language}}$  and  $\gamma_{\text{trade agreement}}$  refer, respectively, to whether countries  $n$  and  $i$  share a language, and whether they have a trade agreement.<sup>16</sup>

Henceforth,  $Y = \{\gamma_1, \gamma_2, \gamma_3, \gamma_{\text{border}}, \gamma_{\text{language}}, \gamma_{\text{trade agreement}}\}$  refers to the set of trade cost parameters and  $\tilde{Y}$  refers to the set of data on countries' pairwise geopolitical characteristics—distance, common border, language, and trade agreement.

*Technology Parameters  $T_i$ .* Given parameters  $\{Y, \theta_A, \theta_B, \alpha_A, \sigma_A, \sigma_B\}$ , data on population  $L$ , and geopolitical characteristics  $\tilde{Y}$ , equilibrium conditions (8) pin down a relation between technology parameters  $\{T_i\}_{i=1}^N$  and market clearing wages  $\{w_i\}_{i=1}^N$ . One can either use technology parameters  $T$  to find market clearing wages  $w$  or use wages to find technology parameters. I use the latter

<sup>16</sup>I use only the trade agreements that the World Trade Organization (WTO) lists as the best known: Association of Southeast Asian Nations (ASEAN), Common Market for Eastern and Southern Africa (COMESA), European Free Trade Association (EFTA), European Union, Mercosur, and North American Free Trade Agreement (NAFTA). Usually, an exponential functional form is assumed for trade costs, for example,  $d_{ni} = \exp(\gamma_1 + \gamma_2 D_{ni} + \gamma_3 D_{ni}^2 + \gamma_{\text{border}} + \gamma_{\text{language}} + \gamma_{\text{trade agreement}})$ , which facilitates log-linearizing regression models. In my estimation procedure, this convenience is useless and the choice between these two functional forms makes no difference in the empirical results. I chose equation (12) because, unlike the exponential function, its parameters are easily interpretable.

approach. I take income per capita from the data as a proxy for wages.<sup>17</sup> Then, for each guess of the parameters, I simulate the whole economy, generating trade flows  $X_{ni}$  until I find technology parameters  $T$  that satisfy equilibrium conditions (8).<sup>18</sup> This procedure reduces the number of parameters to be estimated by  $N = 162$ .

*Empirical Specification.* Let  $z_{ni} = \frac{X_{ni}}{X_n X_i}$  be the trade flow from country  $i$  to country  $n$ , normalized by the product of the two countries' total income  $X_n X_i$  ( $= w_n L_n w_i L_i$ ), and let  $z$  be the corresponding vector. After substituting trade costs of equation (12) and the implicit solutions for technology parameters  $T_i$ , the stochastic form of equation (11) becomes

$$(13) \quad z = h(w, L, \tilde{Y}; Y, \theta_A, \theta_B, \alpha_A, \sigma_A, \sigma_B) + \varepsilon.$$

The vector of trade flows  $z$  is a function  $h$  of the data  $\{w, L, \tilde{Y}\}$  and of the 11 parameters to be estimated  $\{Y, \theta_A, \theta_B, \alpha_A, \sigma_A, \sigma_B\}$ , plus the error term  $\varepsilon$ .

I estimate equation (13) using non-linear least squares (NLLS).<sup>19</sup> Anderson and Van Wincoop (2003) also estimated a trade model with NLLS by simulating the whole economy to get endogenous variables, and their discussion on the error terms holds here. The estimator is unbiased if  $\varepsilon$  is uncorrelated with the derivative of  $h$  with respect to  $w, L$ , and  $\tilde{Y}$ . This assumption holds if the error term is interpreted as measurement error. But error terms can enter the model in many other ways, about which the theory offers no guidance. In particular, one could add an error term to the specification of trade costs in equation (12) to account for the possibility that factors other than the geopolitical characteristics  $\tilde{Y}$  affect trade costs. Then standard econometric theory requires the error term to be uncorrelated with  $\tilde{Y}$ . But even if this condition is satisfied, a problem arises here because changes in trade costs  $d_{ni}$  affect equilibrium wages, which affect the estimates of technology parameters  $T_i$ , which in turn affect trade flows. Simulations suggest, however, that these general equilibrium effects of structural errors in trade costs are likely to be small—introducing large multiplicative shocks to trade costs yields very small changes to equilibrium relative wages.

<sup>17</sup>From a theoretical viewpoint, it is easy to introduce the distinction between population and labor force by making the labor endowment of individuals in country  $i$  equal to a fraction  $\beta_i < 1$ , corresponding to the labor force participation in country  $i$ . While this modification complicates the notation, its impact on the empirical results is nil.

<sup>18</sup>Alvarez and Lucas (2007) proved the existence and uniqueness of equilibrium in the EK model. The new model satisfies standard conditions for existence (Mas-Colell, Whinston, and Green (1995, Chap. 17)), but I do not prove uniqueness. Still, I did not encounter any cases where the relation between  $w$  and  $T$  in the market clearing conditions was many-to-one or one-to-many. In Appendix D, I perform Monte Carlo simulations and find that the parameters are well identified, which suggests that the equilibrium is unique. The United States' technology parameter  $T_i$  is normalized to 1. All Fortran programs are available in the Supplemental Material.

<sup>19</sup>See Appendix C for the normalization of trade flows and scaling of observations.

For the sake of comparison, EK estimated their model by introducing error terms to the trade cost specification and used instrumental variables or fixed effects to avoid endogeneity issues with wages. The estimation procedure above accounts for endogenous wages by simulating the whole economy. Its disadvantage is not correcting for potential endogeneity problems that arise from structural errors in trade costs.<sup>20</sup>

*Identification of  $\sigma$  and  $\theta$ .* EK were not able to identify parameters  $\theta$  and  $\sigma$  from trade data. In the EK model, parameter  $\sigma$  does not enter the expression for trade flows and, assuming exponential trade costs, parameter  $\theta$  enters only as coefficients on trade costs. In the new model, parameters  $\sigma_A$  and  $\sigma_B$  could in principle be identified, because they cannot be factored out of the expression for trade flows. But in practice, fixing different values for  $\theta_A$  and for  $\sigma_A$  does not change the objective function.

Parameters  $\theta_A$  and  $\theta_B$  are not separately identifiable from trade cost parameters  $Y$ . A decrease in  $\theta_A$  and  $\theta_B$  increases the variance of the distribution of technologies, which in turn increases trade across all country pairs. This effect also arises if trade costs  $Y$  decrease. Data on bilateral trade flows do not distinguish between these two changes—a decrease in  $\theta_A$  or in  $Y$ . To recover the remaining parameters, however, I need to fix  $\theta_A$  (or by symmetry,  $\theta_B$ ). I set  $\theta_A = 8.28$ , the median estimate in EK.

Parameters  $\sigma_A$  and  $\sigma_B$  are not separately identifiable either. These parameters govern how spending across types changes with income per capita, but they play no individual role. As in the case of  $\theta_A$ , I need to fix  $\sigma_A$  to estimate the other parameters. I set  $\sigma_A = 5$ , an arbitrary value that satisfies the assumption  $\sigma_A < \theta_A + 1$ .

In Appendix C, I experiment with several values for  $\theta_A$  and  $\sigma_A$ , and find that the objective function does not change, thus confirming that these parameters are not identified. The interpretation of the parameter estimates and of the results below is the same for all values of  $\theta_A$  and  $\sigma_A$  in the Appendix.

### 3.1.2. Data and Parameter Identification

This section explains intuitively the features of the data that allow for the identification of the parameters to be estimated:  $Y$ ,  $\alpha_A$ ,  $\sigma_B$ ,  $\theta_B$ . Without loss of generality, let  $\sigma_A \geq \sigma_B$  so that type  $A$  goods are more income-elastic and govern patterns of trade among rich countries. Given the heterogeneity of production technologies in type  $A$ ,  $\theta_A = 8.28$ , trade flows among rich countries provide information on trade costs  $Y$ . Given  $Y$ , the volume of trade among poor countries provides information on  $\theta_B$ : the larger is  $\theta_B$ , the smaller is the

<sup>20</sup>The problem with using the EK estimation procedure here is not only that it is not applicable to the new model, but it is also not applicable to data sets with zero trade flows (such as the one I use) because it involves taking the logarithm of trade flows.

heterogeneity in type  $B$  production technologies and the smaller is the volume of trade among poor countries.

The volume of trade between rich and poor countries, in turn, provides information on preference parameter  $\sigma_B$  ( $\sigma_A$  is fixed to 5). If the income elasticity of demand is equal across types,  $\sigma_B = \sigma_A$ , the model predicts large volumes of trade between rich and poor countries because these countries specialize in different types of goods. If instead  $\sigma_B < \sigma_A$ , as the empirical results below indicate, demand patterns suppress trade among countries of different income levels. Rich countries demand relatively more type  $A$  goods, generally produced in rich countries, while poor countries demand more type  $B$  goods. Finally, parameter  $\alpha_A$ —the weight of type  $A$  goods in preferences—governs the size of sector  $A$  relative to sector  $B$ , thereby controlling the size of the “rich” and “poor” country groups above.

Appendix D presents Monte Carlo experiments. I simulate data with random parameters, apply the optimization algorithm to simulated data, and find that the algorithm can recover the parameter values with precision.

### 3.1.3. Empirical Specification 1: Results

I first present the results of the new model and then those of the EK model. The third column of Table 1 presents the parameter estimates.<sup>21</sup> The model explains  $R^2 = 42\%$  of the data. Figure 2 plots the contribution of each importer to the objective function—observations in the graph sum to 58% (1–42%). Residuals tend to be larger for small countries, but excluding the 20 smallest countries in the sample does not change the results much.<sup>22</sup>

The new model introduces three parameters to the EK model:  $\alpha_A$ ,  $\sigma_B$ ,  $\theta_B$ . Types  $A$  and  $B$  coexist in the economy,  $(\alpha_A)^{1/\sigma_A} \in (0, 1)$ ; type  $A$  has a higher income elasticity of demand,  $\sigma_A > \sigma_B$  ( $\sigma_A = 5$  and  $\sigma_B = 1.29$ ), and it presents more heterogeneous production technologies,  $\theta_A < \theta_B$  ( $\theta_A = 8.28$  and  $\theta_B = 14.34$ ). Consumption of type  $A$  ranges from 88% of Japan’s gross domestic product (GDP) to  $1 \times 10^{-6}$  of the Democratic Republic of Congo’s, while supply ranges from 99.6% of Luxembourg’s GDP to  $1 \times 10^{-13}$  of the Democratic Republic of Congo’s. The hypothesis that  $\sigma_A > \sigma_B$  and  $\theta_A < \theta_B$  cannot be rejected at a 0.1% significance level.

So rich countries produce and consume relatively more goods with heterogeneous technologies. As a result, they trade a lot, while poor countries trade little. For example, trade among the 20 richest countries in the sample accounts on average for 27% of these countries’ GDP, while trade among the remaining 142 countries accounts for only 16% of these countries’ GDP. The new model predicts that these numbers are 16% and 9%, respectively, while the EK model

<sup>21</sup>Standard errors are clustered by importer and exporter. I use the formula in Cameron, Gelbach, and Miller (2011) for multi-way clustering.

<sup>22</sup>Parameter estimates are within the 99% confidence interval of the original estimates, and the stylized facts of Figures 3, 4, and 5 continue to hold.

TABLE I  
ESTIMATION RESULTS<sup>a</sup>

	EK Model		New Model	
	OECD Only	Full Sample	Specification 1	Specification 2
Normalized parameters				
$\theta_A$	8.28	8.28	8.28	8.28
$\sigma_A$			5.00	
Estimated parameters				
$\gamma_1$	1.24 (0.10)	1.96 (0.08)	1.38 (0.04)	1.28 (0.07)
$\gamma_2$	0.84 (0.23)	0.26 (0.09)	0.20 (0.03)	0.13 (0.03)
$\gamma_3$	-0.21 (0.09)	0.00 (0.03)	-0.01 (0.00)	0.00 (0.00)
Border	0.98 (0.06)	0.85 (0.05)	0.99 (0.07)	0.94 (0.05)
Language	1.01 (0.10)	0.92 (0.06)	0.93 (0.05)	0.93 (0.05)
Trade agreement	0.91 (0.04)	1.27 (0.12)	1.22 (0.12)	1.24 (0.09)
$\theta_B$			14.34 (0.95)	19.27 (3.89)
$(\alpha_A)^{1/\sigma_A}$			0.82 (0.03)	
$\sigma_B$			1.29 (0.10)	
$R^2$	74%	34%	42%	67%
Number of observations	342	25,810	25,810	25,810

<sup>a</sup>Standard errors in parentheses are clustered by importer and exporter.

(below) predicts 2% and 5%, respectively: it underestimates trade in general and reverses the order, predicting less trade among the rich than among the remaining countries.

In Figures 3, 4, and 5, graph (a) refers to the data, graph (b) refers to the EK model, and graph (c) refers to the new model. Figure 3 plots countries' trade share (i.e.,  $\frac{\text{imports}+\text{exports}}{2*\text{GDP}}$ ) against income per capita. Since the estimation procedure implies that observed and predicted incomes, on the  $x$ -axes, are the same, the graphs differ only because of differences between observed and estimated trade shares, on the  $y$ -axes.

The data show an increasing, statistically and economically significant relation between trade share and income per capita. The model correctly predicts the increasing relation, but overestimates its magnitude. The slopes in Figure 3

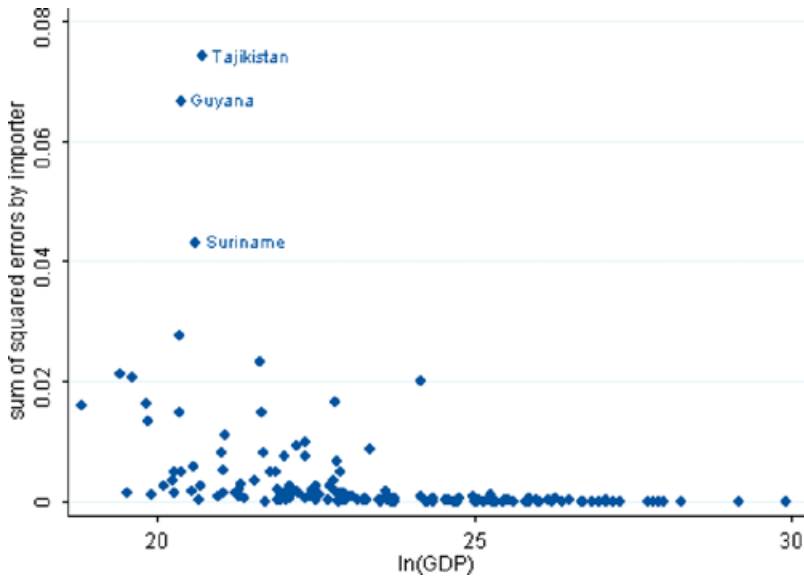


FIGURE 2.—The contribution of each importer in the objective function as a function of its total income.

imply that the richest country in the sample is expected to trade 16% more of its income than in the poorest country according to the data and 36% more according to the model.<sup>23</sup>

Figure 4 substitutes income per capita in the  $x$ -axis of Figure 3 with total income. A country's total income contains little information on its trade share: the slope of the regression line in Figure 4(a) is small and statistically insignificant, and the  $R^2 = 0.01$ . Similarly, the new model predicts a small slope and an  $R^2 = 0.03$ . Size has two opposing forces in the model. First, large countries tend to trade less in general equilibrium. In a two-country world, for example, trade always represents a smaller fraction of the large country's income than of the small country's. Second, large countries tend to be richer and hence trade more.

Figure 4(a) and (c) both display large variance in trade shares among countries of medium size. Countries with high income per capita and small population have large trade shares (e.g., Singapore and Hong Kong), while countries with low income per capita and large population have small trade shares (e.g., Pakistan and Bangladesh).

Figure 5 illustrates countries' choice of trading partners. For each country, I calculate the fraction of its trade that flows to or from one of the 20 richest

<sup>23</sup>These countries are Luxembourg and the Democratic Republic of Congo, and the ratio of their income per capita is 538.

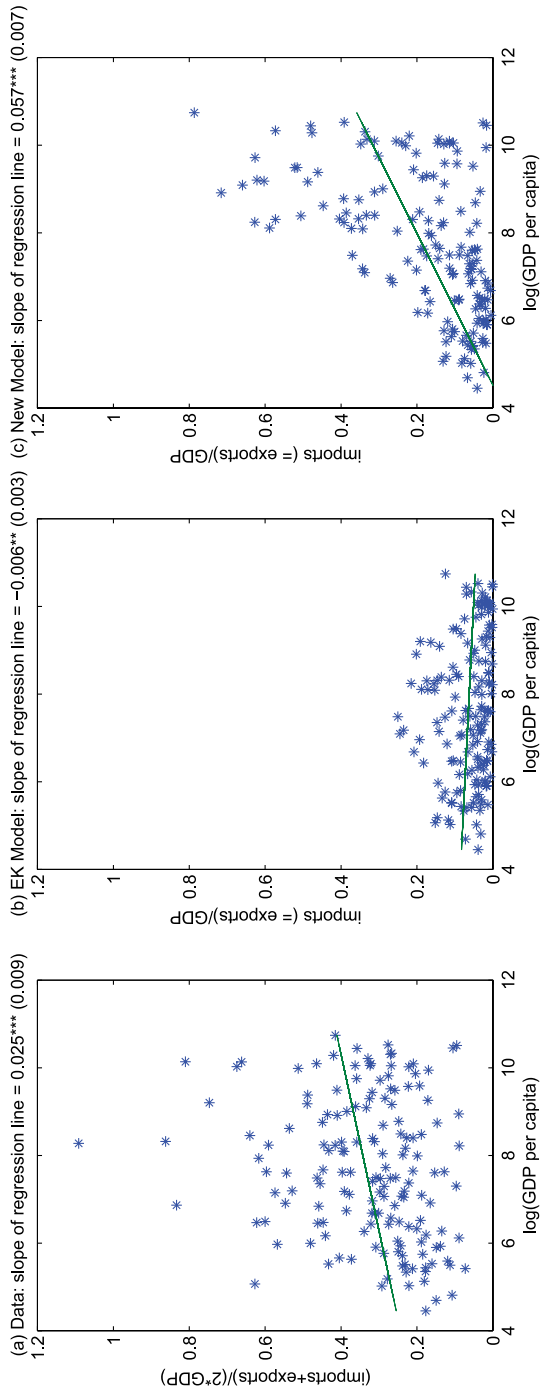


FIGURE 3.—Income per capita  $\times$  trade share.

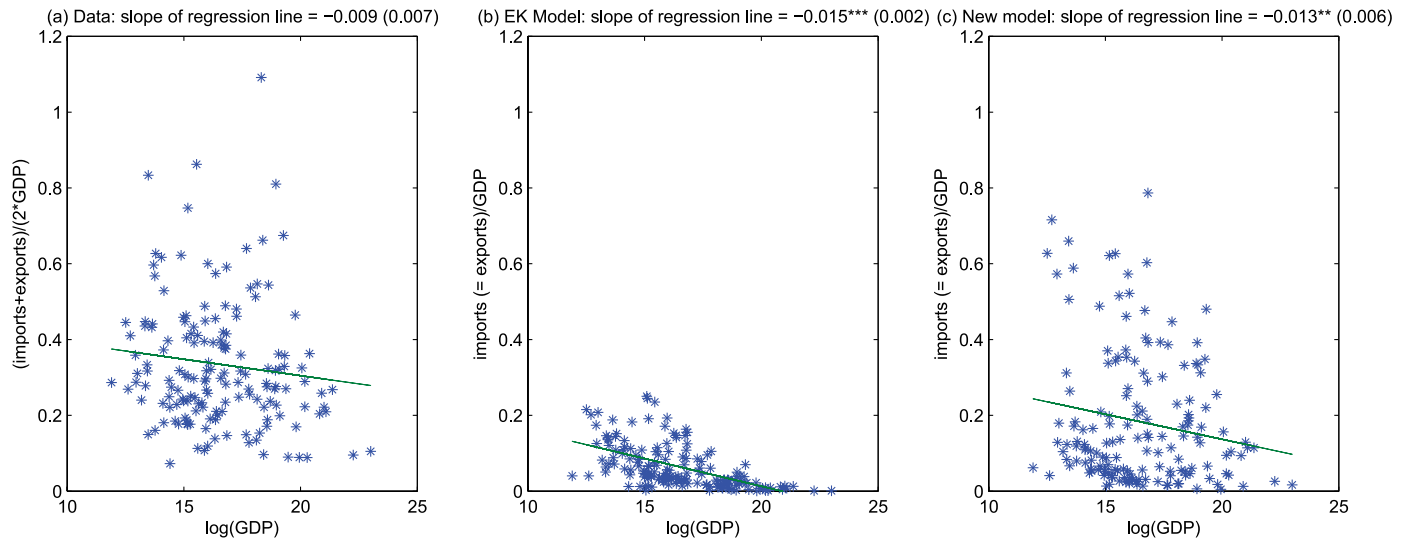


FIGURE 4.—Total income  $\times$  trade share.

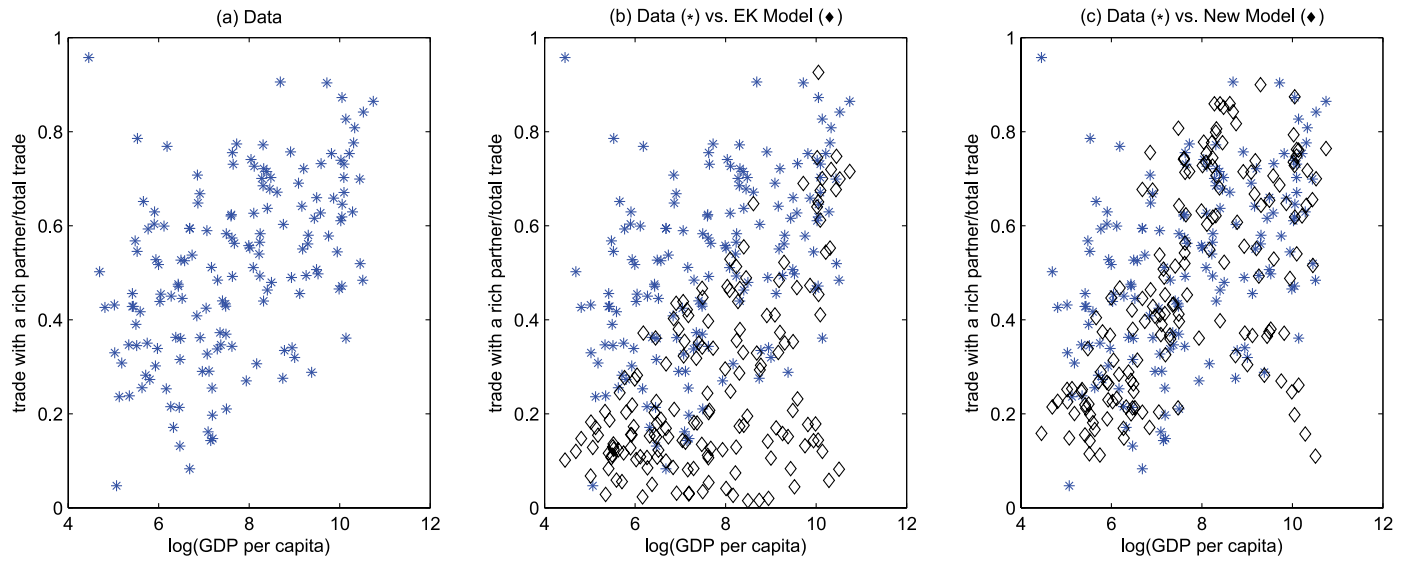


FIGURE 5.—Income per capita  $\times$  trade with 20 richest countries.

countries in the sample. Figure 5 plots this fraction against income per capita. Graph 5(a) refers to the data and graph 5(c) depicts both observations of the data (asterisks) and of the model (hollow diamonds). The observations of the model are well aligned with the data. In particular, both graphs show an increasing relation: rich countries trade relatively more with other rich countries.

*The EK Model.* The EK model provides a good benchmark for the results above because the new model is built on EK and EK delivers the gravity equation. Using the procedure in Section 3.1.1 above, I estimate the EK model twice—once with the full sample and once with a subsample of the 19 OECD countries used by EK.<sup>24</sup> Table I presents the results. EK used their model to study manufacturing trade among OECD countries, while I study trade across countries of different sizes and income levels. So, not surprisingly, the EK model predicts very well trade among OECD countries, but not trade in the full sample—the  $R^2$  decreases from 74% with the OECD sample to 34% with the full sample. Moreover, the EK and the new model yield similar predictions for the OECD sample, but not for the full sample.<sup>25</sup>

The EK model cannot reconcile the large volumes of trade among rich countries with the small volumes among poor countries. As  $(\hat{\gamma}_1, \hat{\gamma}_2, \hat{\gamma}_3)$  changes from (1.24, 0.84, -0.21) in the OECD sample to (1.96, 0.26, -0.001) in the full sample, trade costs increase for all OECD country pairs, and they increase by 80% on average. More generally, the model is not flexible enough to predict the increasing relationship between trade shares and income per capita (Figure 3). As a result, it systematically overestimates the share of poor countries in trade (Figure 5(b)). To correct for this shortcoming without overestimating trade among poor countries, the model underestimates trade shares for all countries.<sup>26</sup>

### 3.2. Empirical Specification 2: Importer Fixed Effects

Trade flows in equation (11) can be rewritten as

$$(14) \quad z_{ni} = \frac{X_{ni}}{X_n X_i} = \frac{X_{nA}}{X_n} \left( \frac{T_i (d_{ni} w_i)^{\theta_A}}{X_i \Phi_{nA}} \right) + \left( 1 - \frac{X_{nA}}{X_n} \right) \left( \frac{T_i (d_{ni} w_i)^{\theta_B}}{X_i \Phi_{nB}} \right).$$

<sup>24</sup>With the EK model, after normalizing parameter  $\theta_A$  and backing out the technology parameters  $T_i$ , trade flows are exclusively a function of trade cost parameters  $Y$ . Parameters  $\alpha_A$ ,  $\sigma_A$ ,  $\sigma_B$ , and  $\theta_B$  do not exist or do not affect trade flows in the EK model (see equation (10)).

<sup>25</sup>The results of the new model with the OECD sample are not given in the table. Even though the new model adds three free parameters to EK, the  $R^2$  increases by only 0.5%, and the equivalence of the two models cannot be ruled out since  $\alpha_A^{1/\sigma_A}$  is not statistically different from 1.

<sup>26</sup>See Appendix C for a discussion on the weighting of observations. The finding that the EK model does not reconcile the large volumes of trade flows observed among large, rich countries with the small volumes of poor countries is robust to the choice of weights. But if more weight is placed on large relative to small countries, the model tends to *overestimate* trade among poor countries instead of *underestimating* trade among rich countries, as it does here.

The share of country  $i$  in country  $n$ 's imports is a weighted average of its share in the two types of goods, where the weight  $\frac{X_{nA}}{X_n}$  is the share of type  $A$  in country  $n$ 's spending. The empirical specification below takes the weights  $\frac{X_{nA}}{X_n}$  as importer fixed effects, denoted by  $F_n = \frac{X_{nA}}{X_n}$ . The rest follows Section 3.1.1 above: equation (12) specifies trade costs  $d_{ni}$ , and technologies  $T_i$  are implicitly defined through the market clearing conditions. Then

$$(15) \quad z = g(w, L, \tilde{Y}; F, Y, \theta_A, \theta_B) + \epsilon.$$

Normalized trade flows  $z$  are a function  $g$  of the data on income per capita  $w$ , population  $L$ , and geopolitical characteristics  $\tilde{Y}$ , and of the 170 parameters to be estimated—the vector of  $N = 162$  fixed effects  $F$ , six trade cost parameters  $Y$ , and  $\theta_A$  and  $\theta_B$ —plus an error term  $\epsilon$ .

I estimate equation (15) using NLLS. If specification (13) is consistent, then specification (15) is also consistent. The first specification (13) is more efficient, and the second (15) is more robust because it makes fewer assumptions on demand: it does not specify how spending across types  $A$  and  $B$  varies with importer characteristics. As in specification (13), parameter  $\theta_A$  is not identifiable in practice. I fix  $\theta_A = 8.28$  and obtain the same results with different values for  $\theta_A$  in Appendix C.

The last column of Table I presents the results. The estimates of  $Y$  and  $\theta_B$  do not change much from the previous estimates (third column).<sup>27</sup> As before, rich countries produce and consume relatively more type  $A$  goods. These goods have more heterogeneous technologies ( $\theta_A < \theta_B$ ), and their share in spending (fixed effects) is increasing in income per capita, as shown in Figure 6. The latter pattern remains even after controlling for prices, which suggests that type  $A$  has a higher income elasticity of demand.

I use the fixed effects to estimate demand parameters. From equation (5),

$$F_n = [(\lambda_n)^{-\sigma_A} \alpha_A P_{nA}^{1-\sigma_A}] / w_n \quad \text{for all } n = 1, \dots, N,$$

where  $P_{n\tau} = [\Gamma(\frac{\theta_\tau + 1 - \sigma_\tau}{\theta_\tau})]^{1/(1-\sigma_\tau)} (\Phi_{n\tau})^{-1/\theta_\tau}$ , with  $\Phi_{n\tau} = \sum_{i=1}^N T_i(d_{ni}w_i)^{-\theta_\tau}$ . The term  $(\Phi_{n\tau})^{-1/\theta_\tau}$  depends exclusively on parameters  $T$ ,  $Y$ , and  $\theta_\tau$ , estimated in equation (15). Then

$$(16) \quad F_n = k(w_n, \Phi_{nA}^{-1/\theta_A}, \Phi_{nB}^{-1/\theta_B}; \alpha_A, \sigma_A, \sigma_B) \quad \text{for all } n = 1, \dots, N.$$

<sup>27</sup>Testing for the equality of the supply side parameters  $\{Y, \theta_B\}$  would be useful to check for the consistency of the model, but it is a complicated statistical problem. Standard tests do not apply because the covariance across the two estimators is unknown. Furthermore, the error terms in equations (13) and (15) are heteroskedastic and clustered by importer and exporter, making bootstrapping infeasible (without ad hoc structural assumptions on the distribution of error terms).

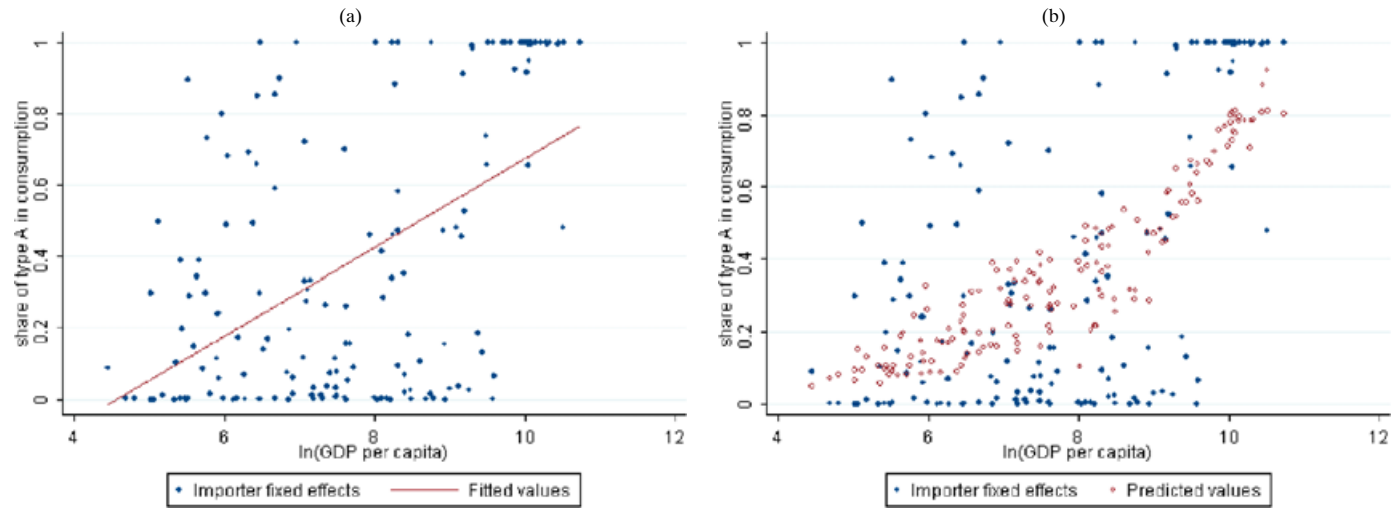


FIGURE 6.—(a) The coefficient on log of per capita income is 0.12 (standard error 0.02) and it is 0.08 (0.02) with price controls. (b) Importer fixed effects and their estimates as a function of income per capita.

Fixed effects  $F_n$  are a function  $k$  of wages  $w_n$ , price terms  $(\Phi_{n\tau})^{-1/\theta_\tau}$ , and preference parameters  $\alpha_A$ ,  $\sigma_A$ , and  $\sigma_B$ . I estimate  $\{\alpha_A, \sigma_A, \sigma_B\}$  nonlinearly from equation (16) using the first-stage estimates for  $F_n$ ,  $\Phi_{nA}^{-1/\theta_A}$  and  $\Phi_{nB}^{-1/\theta_B}$  as data. As before, I fix  $\sigma_A = 5$ .

Figure 6(b) compares the fixed effects of the first-stage estimation to their predicted values. The parameter estimates are  $\alpha_A^{1/\sigma_A} = 0.68$  and  $\sigma_B = 3.46$ . Hence, the fundamental results from specification (13) hold in the more robust specification (15): trade patterns in the data support the hypothesis that goods with more heterogeneous technologies have higher income elasticity of demand ( $\theta_A < \theta_B$  and  $\sigma_A > \sigma_B$ ).

#### 4. COUNTERFACTUALS

I now analyze counterfactuals. Since the model is highly stylized, the purpose of the exercise is not to pursue policy recommendations, but a better understanding of the model itself. Section 4.1 experiments with technology shocks and Section 4.2 experiments with changes in trade costs.

The procedure is as follows. An economy is defined with the population of each country, taken from the data, and with the estimates from Section 3.1 of parameters  $T$ ,  $\alpha_A$ ,  $\sigma_A$ ,  $\sigma_B$ ,  $\theta_A$ ,  $\theta_B$ , and of the matrix of trade costs  $d_{ni}$  through the estimate of  $Y$ . Initially, wages in the data clear the market. For each counterfactual, I change the parameters that define the economy, solve the market clearing conditions (8) to get new wages, and recalculate utility in every country.

##### 4.1. Technology Shocks

A technology shock in country  $i$  is a unilateral increase in its technology parameter  $T_i$ . Its welfare impact depends on the net exports of the different types of goods because relative prices generally change. Figure 7 plots the production, demand, and net exports of type  $A$  goods as a fraction of GDP, against income per capita. Each observation corresponds to a country. The circles denote the share of type  $A$  in production, and the triangles denote its share in demand. Both curves are upward sloping because richer countries produce and consume relatively more type  $A$  goods. The crosses are the net exports of type  $A$  (production minus demand). They form a V-shaped curve: they are small for low- and high-income countries and large and negative for middle-income countries. Low-income countries produce and consume mostly type  $B$ ; high-income countries produce and consume type  $A$ ; middle-income countries consume more type  $A$  goods than they produce. Patterns for type  $B$  are implicit in Figure 7, since their demand and supply equal 1 minus the demand and supply of type  $A$ .

Bilateral imbalances mostly explain the pattern in Figure 7. As the figure suggests, the trade deficit with rich countries is larger for middle- than for low-income countries in the data and in the model. So even with symmetric trade

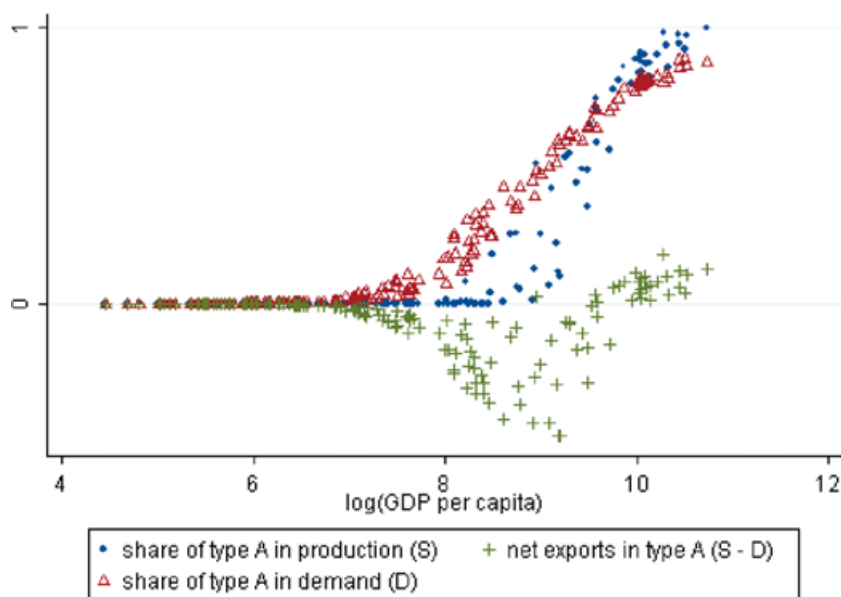


FIGURE 7.—Production, demand, and net exports of type *A* goods.

costs, the model can generate bilateral imbalances to better fit the data. To check for this explanation, I eliminate bilateral imbalances from the data by imputing for each country pair the average between their imports and exports. When the model is estimated with these modified data, the lag between demand and supply of type *A* goods in Figure 7 largely (though not completely) disappears. This lag also implies, in general equilibrium, that rich countries are net exporters of high income-elastic goods, a prediction that is consistent with theoretical work on trade and nonhomothetic preferences.<sup>28</sup>

Between 1985 and 2000, China grew nearly four times relative to the rest of the world. To view the effects of continued growth in China, I increase China's technology parameter  $T_{\text{China}}$  until its wages increase by 300% relative to the rest of the world. Chinese consumption of type *A* goods increases from 1% to 21% of GDP, and its production increases only from  $1 \times 10^{-7}$  to 3%. Two price changes ensue. First, the price of type *B* decreases relative to wages in most countries, because the productivity gains accrue mostly to goods of type *B*, in which China specializes. This price change benefits primarily poor countries, the largest consumers of type *B* goods. Second, the price of type *A* goods

<sup>28</sup>See Fajgelbaum, Grossman, and Helpman (2009), Flam and Helpman (1987), Matsuyama (2000). Empirically, Choi, Hummels, and Xiang (2009), Fieler (2011a), and Schott (2004), among others, find that unit prices in trade increase with importer and exporter per capita income. If prices proxy quality levels, this suggests that high-income countries trade relatively more high-quality goods, but it is not a finding about net exports.

increases relative to type  $B$ , because their demand increases more than their supply. This price change benefits rich countries, net exporters of type  $A$ , and it hurts middle-income countries, the largest net importers of type  $A$ .

In sum, the shock in China benefits poor and rich countries, and it hurts most middle-income countries. Wages in the 50 richest countries increase by 5.4% relative to the 50 poorest countries. The largest real wage increases occur in China's rich and poor neighbors (e.g., Hong Kong (3.5%), Mongolia (2.1%), and Japan (1.0%)) and the largest real wage decreases occur in China's middle-income neighbors (e.g., Malaysia (-0.6%) and Thailand (-0.3%)).

This prediction is broadly consistent with the evolution of world income from 1980 through 2000, illustrated by Leamer (2007) and Leamer and Schott (2005): income per capita increased in rich and poor countries, and it largely stagnated in middle-income countries. Leamer and Schott conjectured that the growth of China and India hurt middle-income countries because these countries compete directly with goods produced in poor countries, while rich countries specialize in other goods. The model encompasses this mechanism and adds to it the possibility for poor countries to gain as consumers of Chinese and Indian goods.

Next, I experiment with an increase in the United States' technology parameter  $T_{US}$  that increases American wages by 25% relative to the rest of the world. Contrary to the shock in China, a shock in the United States decreases the price of type  $A$  goods relative to wages and to type  $B$  goods. It thus inverts the welfare effects of the Chinese shock: all middle-income countries benefit from the shock; most rich countries are made worse off and poor countries are left close to indifferent. The shock decreases nominal wages in the 30 richest countries in the sample by 1.1% relative to the rest of the world. The largest real wage increases occur in Mexico (0.3%) and in small, middle-income Central American countries (approximately 2.5%). Japan, Norway, and Switzerland experience small welfare losses.

#### 4.2. Trade Barriers

I consider two extreme changes in trade barriers: (i) eliminating trade barriers ( $d_{ni} = 1$ ) and (ii) raising trade barriers to autarky levels ( $d_{ni} \rightarrow \infty$  for all  $n \neq i$ ). As in standard models, small countries are the most affected by changes in trade costs, but different from standard models, after controlling for size, poor countries are less affected than rich countries. Eliminating trade barriers benefits all countries. Real wages increase by 16% in the United States and by more than 140% in some small countries. A move to autarky, in turn, makes all countries worse off. Real wages decrease by 0.1% in India and by 18% in Luxembourg. So, as others have found, changes in welfare are larger when the world moves to frictionless trade than to autarky (Waugh (2010)).

## 5. EXTENSIONS

I introduce into the model income inequality within countries in Section 5.1 and intermediate inputs in Section 5.2.

5.1. *Income Inequality*

Income inequalities within countries affect demand patterns and, thereby, trade. For 121 countries in the sample, the World Bank (2008) provides data on the share of income held by each quintile of the population. I use these data to reestimate the model for this subset of countries. Instead of calculating demand for a single representative consumer in each country, I calculate it for five consumers, each representing one income quintile. A country's total demand is the sum of these representative consumers weighted by 20% of the population.

Introducing income inequality within countries does not change the results in Section 3. Parameter estimates practically do not change, and the  $R^2$  increases by 1% in the first specification (13) and it decreases by 0.2% in the second (15). Because of this small difference and because of the paucity of data on income distribution, Section 3 above presents only the results with no income inequality within countries.<sup>29</sup>

5.2. *Intermediate Inputs*

The model of Section 2 can be extended to admit intermediate inputs, as in Eaton and Kortum (2002). Instead of only labor, assume that production requires a Cobb–Douglas bundle of inputs. The cost of each input bundle is

$$c_{i\tau} = w_i^{1 - \sum_{\tau'=1}^S \beta_{\tau\tau'}} \prod_{\tau'=1}^S (P_{i\tau'})^{\beta_{\tau\tau'}} \quad \text{for } \tau = 1, \dots, S,$$

where  $\beta_{\tau\tau'} > 0$  is the share of goods of type  $\tau'$  in the production of type  $\tau$ , and  $(1 - \sum_{\tau'=1}^S \beta_{\tau\tau'}) > 0$  is the labor share.

Country  $n$ 's absorption of type  $\tau$  is

$$(17) \quad X_{n\tau} = \left[ \sum_{\tau'=1}^S \left( \frac{\beta_{\tau'\tau}}{1 - \sum_{\tau''=1}^S \beta_{\tau'\tau''}} \right) w_n L_{n\tau'} \right] + L_n x_{n\tau},$$

<sup>29</sup>Data are available for only 121 countries, and even these countries only report the distribution of income sporadically. To collect data, I used reports from 1990 to 2007, giving priority to the information available in the year closest to 2000, the year of the trade data.

where  $L_{n\tau}$  is the labor of country  $n$  allocated to the production of type  $\tau$ , and  $x_{n\tau}$  is the per capita final consumption of type  $\tau$  in country  $n$ . Assuming utility function (1),  $x_{n\tau}$  is given by equation (5):  $x_{n\tau} = \lambda_n^{-\sigma_\tau} \alpha_\tau P_{n\tau}^{1-\sigma_\tau}$ , where  $\lambda_n$  is the Lagrange multiplier, implicitly defined through the budget constraint  $w_n = \sum_{\tau=1}^S x_{n\tau}$ . Additionally, assuming the distribution of efficiencies in equation (3), country  $n$ 's imports of goods of type  $\tau$  from country  $i$  are

$$(18) \quad X_{ni\tau} = \frac{T_i(d_{ni}c_{i\tau})^{-\theta_\tau}}{\Phi_{n\tau}} X_{n\tau},$$

where  $\Phi_{n\tau} = \sum_{i=1}^N T_i(d_{ni}c_{i\tau})^{-\theta_\tau}$ . The CES price indices are  $P_{n\tau} = [\Gamma(\frac{\theta_\tau+1-\sigma_\tau}{\theta_\tau})]^{1/(1-\sigma_\tau)} (\Phi_{n\tau})^{-1/\theta_\tau}$ . So the only change in trade shares  $\frac{X_{ni\tau}}{X_{n\tau}}$  and in the price indices is the substitution of wages  $w_i$  for the cost of the input bundle  $c_{i\tau}$ . The market clearing conditions are

$$(19) \quad w_i L_{i\tau} = \left(1 - \sum_{\tau'=1}^S \beta_{\tau\tau'}\right) \sum_{n=1}^N X_{ni\tau} \quad \text{for } i = 1, \dots, N \text{ and } \tau = 1, \dots, S,$$

and

$$(20) \quad L_i = \sum_{\tau=1}^S L_{i\tau} \quad \text{for } i = 1, \dots, N.$$

This completes the statement of the model with intermediate inputs. An equilibrium is a set of wages  $\{w_i\}_{i=1}^N$  and a set of labor allocations  $\{\{L_{i\tau}\}_{i=1}^N\}_{\tau=1}^S$  that satisfy the system of equations (19) and (20), where the terms  $X_{ni\tau}$  are given by equations (17) and (18).

Empirically, there are a few differences between the model with and without intermediates. First, without intermediates, countries cannot trade more than their total income (which is clearly not a binding constraint in the empirical exercise of Section 3). Second, there are two potential sources of nonhomotheticity in demand in equation (17). To understand them, suppose again that there are only two types,  $A$  and  $B$ , and that type  $A$  presents more heterogeneous technologies ( $\theta_A < \theta_B$ ) so that, in equilibrium, countries with large technology parameters  $T_i$  have high wages and specialize in type  $A$ . Then rich countries consume relatively more type  $A$  goods either if type  $A$  is more income-elastic ( $\sigma_A > \sigma_B$ , as before) or if producing type  $A$  goods requires relatively more type  $A$  intermediates ( $\frac{\beta_{AA}}{\beta_{AB}} > \frac{\beta_{BA}}{\beta_{BB}}$ ), or both. Data on total trade flows do not distinguish between these possibilities, so the parameters introduced by the model with intermediate goods are not identified in the data.<sup>30</sup>

<sup>30</sup>See Yi (2003) for a study of intermediate goods in trade.

## 6. CONCLUSION

An integrated trade model, one that provides a single framework for trade among rich countries as well as trade among countries of different income levels, has long concerned economists. Generally speaking, North–North trade is explained through the differentiation of goods and services, while North–South trade is explained through differences in comparative advantage due to technologies or factor endowments. This paper proposes a model that delivers both North–North and North–South patterns. Trade among rich countries occurs primarily in differentiated goods, while trade of rich with poor countries occurs across sectors.

A quantitative comparison of the predictions on trade flows of this integrated model to those of a gravity model shows the benefits of the integrated approach. Theoretical foundations of the gravity relationship are typically based on intraindustry trade of differentiated goods. So, not surprisingly, the EK gravity model explains trade among the rich OECD countries well but not trade among countries of different income levels. The new model, in turn, explains trade among OECD countries as well as EK and it explains trade in the sample with 162 countries much better than EK. For example, the model correctly predicts extensive trade among rich countries and scant trade among poor countries.

I use the parameter estimates of the model to analyze counterfactuals. The model qualitatively predicts some effects from a technology shock in China that are often put forth by the popular press: the shift in Chinese demand and production toward luxury goods; the global decrease in the prices of low-end manufactures such as toys and textiles; the negative wage pressure experienced by textile industries in Malaysia, the Philippines, and Thailand; and the benefits accrued by Hong Kong and Singapore for selling high-end products, such as financial services, to China and other fast-growing East Asian economies. In the model, these changes benefit poor and rich countries, and they hurt middle-income countries—a prediction broadly consistent with the evolution of world income between 1980 and 2000, discussed in Leamer (2007) and Leamer and Schott (2005).

Two features of the data, ignored throughout, are potentially useful in future research. First, data are available at the product level. Thus, the links between income elasticity of demand, and production and trade patterns in the model may be verifiable. A growing literature infers quality differences from unit prices and quantities within commodity categories, and finds systematic patterns of trade within categories.<sup>31</sup> In contrast, I infer types of goods from aggregate data. Combining these micro and macro approaches may be fruitful.

<sup>31</sup>See, for example, Hallak (2006), Hallak and Schott (2011), Khandelwal (2010), and Schott (2004).

Second, the data are available for several years. I have emphasized throughout the analogy between product cycles and the variability in production technologies in the model. So a dynamic version of the model should be fit to study the effects of nonhomothetic preferences on technology diffusion and the evolution of trade and growth.

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