Out of Sample Gravity

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May 2017

Abstract

Despite their empirical success, gravity trade models are often criticized for their out-of-sample predictive power with respect to (i) the spatial variation in export prices and (ii) the change in trade shares over time. This paper argues that (i) relaxing the quality-quantity isomorphism and (ii) allowing for less-restrictive cross-elasticity effects, greatly enhances the out-of-sample predictive power of the gravity models. I fit a model featuring these amendments to bilateral trade data from 100 countries. The amended model displays a 25% improved (in-sample) fit compared to the standard model, and can replicate the (out-of-sample) variation in trade structure over time. Given theses improvements, the amended model delivers distinct and more credible counterfactual predictions. Most notably, compared to the standard model, the predicted gains from trade are more dispersed and systematically favor high-income nations.

*Many people have provided helpful comments and suggestions that improved this paper. I am especially thankful to Jonathan Eaton, James Tybout, and Stephen Yeaple for their advice and encouragement. I also thank seminar participants at the University of British Columbia, University of California Santa Cruz, Chicago Fed, Drexel University, Indiana University, Pennsylvania State University, the New Faces in International Economics conference, the Midwest Trade Meetings, the InsTed workshop, and UECE Lisbon Meetings for helpful comments and suggestions. All errors are my own. Correspondence: alashkar@indiana.edu.

1 Introduction

Lately, gravity models featuring multiple sectors with varying trade elasticities have been employed extensively to study the causes and consequences of international trade. Undoubtably, this widespread adoption reflects the various merits of these models. In addition to displaying improved predictive power relative to one-sector alternatives, multi-sector gravity models also deliver more realistic counterfactual predictions, especially with regards to the gains from trade (Costinot and Rodríguez-Clare (2014); Ossa (2015)).

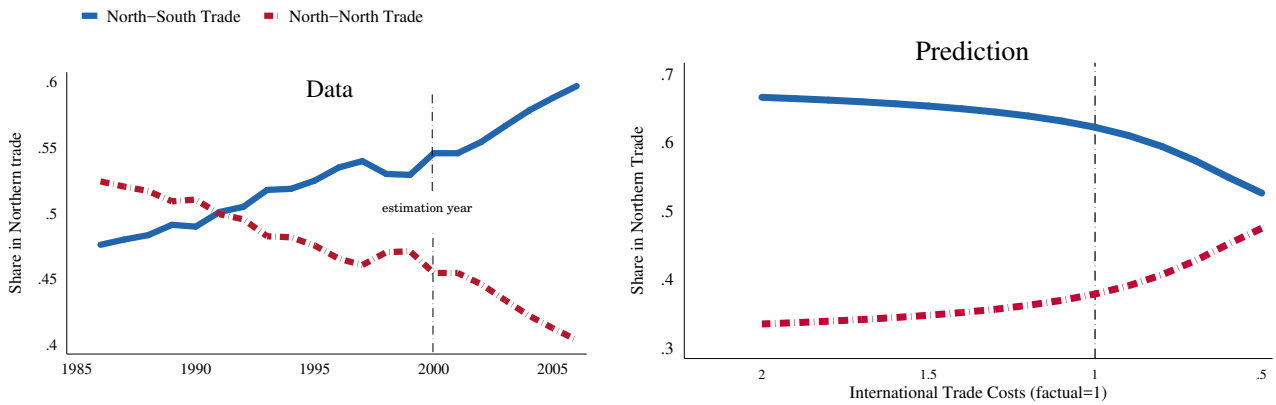
Despite their empirical success, multi-sector gravity models are still subject to two lines of criticism regarding their out-of-sample predictive power. First, gravity models seem incompatible with the spatial variation in export unit-prices (Baldwin and Harrigan (2011)). These variations are widely documented, constituting what is arguably one of the most celebrated regularities in empirical trade: the "Washington apples" effect. Second, gravity trade models are often criticized for their poor out-of-sample performance in the longitudinal dimension—a gravity model fitted to data from a given year cannot replicate the time-series variation in trade values (Lai and Trefler (2002); Kehoe (2005)).[1]

Given that gravity trade models are often used to conduct counterfactual analyses, out-of-sample predictive power bears especial significance. For example, consider the decline of trade costs over the past two decades, which coincides with a remarkable rise in the relative importance of North-South trade. As displayed in Figure 1, a standard two-sector Krugman model fitted to bilateral trade data in the year 2000, cannot replicate these out-of-sample developments. In fact, if anything, the model predicts the opposite pattern—i.e., a rise in the relative importance of North-North trade in response to a decline in trade costs. Considering that most counterfactual analyses in the gravity literature concern a decline in trade costs, the above observation poses a real concern.

One approach to attaining more credible counterfactual predictions, is developing

[1] Some studies, most notably Donaldson (2010), have found that that gravity framework displays good out-of-sample predictive power. Donaldson (2010), however, analyzes an environment where trading entities were relatively homogeneous. He analyzes a reduction in intra-national trade costs by looking at one of history's great transportation projects: the network of railroads built in colonial India from 1870 to 1930. He finds that 86% of the total impact of the railroads on real income in an average district can be explained by the multi-sector Eaton and Kortum (2002) model.

Figure 1: *Out-of-sample predictive power: Standard Two-Sector Krugman Model*



Note: The data is from Head, Mayer, and Ries (2010). The 21-richest countries in 2000 are categorized as Northern countries, and the remaining countries in the sample are categorized as the South. The prediction corresponds to a standard two-sector Krugman model fitted to cross-sectional trade values in 2000—see Section 3 for estimation details.

gravity models with a many degrees of freedom. For example, the latest version of the GTAP model described in Dimaranan, McDougall, and Hertel (2006) has more than 13,000 structural parameters. This approach, however, hinders the parsimony of the gravity framework. An alternative approach is to relax the parametric restrictions imposed by standard gravity models, without sacrificing the underlying parsimony (Adao, Costinot, and Donaldson (2017)).

In this paper I take the latter approach. I propose *two* simple amendments, that greatly enhance the predictive power of the gravity model with respect to (i) the out-of-sample variation in export unit-prices and (ii) the out-of-sample longitudinal variation in global trade patterns. Importantly, both amendments are motivated by micro-level evidence and retain the parsimony of the gravity framework.

The first amendment is relaxing the *quality-quantity isomorphism*—a parametric assumption widely-used in quantitative trade models (see Melitz (2003)). The quality-quantity isomorphism has two rather unsatisfactory implications. First, it implies that high-income countries have a comparative advantage in less differentiated (high elasticity, less tradable) sectors. Second, it entails a weak link between the trade elasticity, which reflects the degree of tradability, and markup/unit price.

Relaxing the quality-quantity isomorphism creates a systematic and robust link

between tradability and price, whereby high-price goods become systematically more tradable and travel longer distances. This pattern gives rise to the "Washington apples" effect, which has long eluded standard gravity models. Additionally, relaxing the quality-quantity isomorphism entails that high-income countries have a comparative advantage in more differentiated (low trade elasticity) sectors. This outcome aligns with micro-level evidence, and at the macro-level enhances both the *in-sample* and *out-of-sample* predictive power of the gravity model.

The second amendment is relaxing the strong parametric restrictions imposed on *cross-elasticity effects*. In particular, instead of assuming constant expenditure shares across sectors, I introduce flexible cross-elasticity effects such that sectoral expenditure shares vary in response to external shocks. This modification has two attractive implications. First, it goes a long way in explaining the structure of trade between rich and poor countries. More importantly, this amendment greatly improves the gravity model's ability to capture the out-of-sample variations in trade structure. For example, an amended gravity model featuring flexible cross-elasticity effects can exactly replicate the transformation in global trade patterns over time—a transformation so dramatic, that Krugman (2009) argues it leaves modern gravity frameworks obsolete.

To demonstrate these arguments quantitatively, I fit both the standard and the amended multi-sector gravity models to bilateral aggregate trade data from 2000. The data set covers 100 countries that vary significantly in size, income and geography. This exercise highlights two merits of the amended model. First, with the same number of free moving parameters, the amended model displays a 25% improved in-sample fit. This improvement reflects the amended model's ability to capture the higher volume of North-North trade relative to South-South trade—the standard model, in comparison, predicts that low-wage countries produce and consume relatively more of the low-elasticity (highly tradable) goods, leading to counterfactually high levels of South-South trade.

Second, the amended model displays improved out-of-sample predictive power. In particular, unlike the standard model, the amended model (fitted to cross-sectional trade data from 2000) can exactly replicate the out-of-sample variation in trade composition, highlighted in Figure 1. This improvement is driven by the prediction that high-wage countries have a comparative advantage in low-trade elastic-

ity sectors, plus the flexible expenditure structure which evolves in response to an external decline in trade costs. This out-of-sample improvement is of special relevance, given that most counterfactual analyses conducted in the gravity literature involve a reduction in trade costs.

Given its marked improvement in reproducing observable out-of-sample variations, the amended model delivers counter-factual predictions that are arguably more credible. I analyze two of these predictions. First, I compute the welfare consequences of trade liberalization, and compare them across the standard and amended gravity models. Whereas the standard model predicts a decline in real cross-national income inequality, the amended model predicts that cross-national income inequality increases in response to trade liberalization. Intuitively, the standard gravity framework predicts that trade liberalization contracts high-elasticity sectors in which high-wage countries have a comparative advantage in. In comparison, the amended model predicts that trade liberalization expands sectors in which high-wage countries have a comparative advantage in, thereby increasing cross-national income inequality.

My second counterfactual analysis concerns the gains from trade relative to autarky—recently, the invariance of these gains across different gravity frameworks, has been the topic of heated discussion (Arkolakis, Costinot, and Rodriguez (2012)). Comparing the computed gains from trade between the standard and the amended gravity models, I find that while the gains are not substantially different in levels, they are considerably more dispersed from the perspective of the amended model. In particular, relative to the standard model, the gains from trade systematically favor high-income nations due to their underlying comparative advantage in highly differentiated (low-elasticity) sectors.

Admittedly, the amended model despite its merits is quite simplistic. It outlines an elementary step towards attaining more credible counterfactual predictions within the gravity framework. In that regard, this paper is related to two contemporary strands of literature. The first emphasizes a non-parametric approach to counterfactual predictions (Adao et al. (2017)). The second strand revises the standard parametric assumptions that underly gravity models—e.g., Caliendo and Parro (2014) who introduce a flexible input-output structure to enhance the predictive power of the competitive multi-sector gravity framework. The approach in this

paper falls under the latter category. Relatedly, my approach shares common elements with studies that have amended the gravity framework for better in-sample predictive power (e.g., Waugh (2010), Fieler (2011)).

The assertion that high-income countries have a comparative advantage in more differentiated (low-trade elasticity) product categories originates in Helpman and Krugman (1985), and has been recently invoked by Hanson and Xiang (2004), Fieler (2011), and Fajgelbaum, Grossman, and Helpman (2011). My contribution to this literature is two-fold. First, I show that specialization across low- and high-elasticity categories has sharp and robust implications about the price composition of exports—most notably, it can explains the "Washington apples" effect. Second, I highlight and quantify how this pattern of specialization influences the structure of cross-national consumption.

Finally, at a broader level, this paper contributes to a vibrant discourse revolving around the gains from trade. In general, existing arguments are primarily focused on the level of the gains and their invariance across gravity frameworks (Arkolakis et al. (2012); Melitz and Redding (2015)). This paper highlights how the underlying micro-structure modifies the cross-national distribution of the gains from trade without altering the overall level of these gains—this finding is reminiscent of those highlighted in Costinot and Rodríguez-Clare (2014), Kucheryavyy, Lyn, and Rodríguez-Clare (2016), and Lashkaripour and Lugovskyy (2017), but in an alternative context.

2 Theory

My point of departure is a standard multi-sector extension of Krugman (1980), which I refer to as the *standard* gravity model. After laying out the standard gravity model, I first highlight its shortcomings in capturing salient trading patterns. Then, I introduce an *amended* gravity model that tractably accounts for these overlooked patterns.

2.1 The Standard Gravity Model.

The Environment. The global economy consists of N countries. Labor is the only factor of production, with L_i denoting the size of the labor force in country i. There are Z categories of goods (or sectors) in the economy indexed by z, each of which comes in a continuum of differentiated firm-specific varieties. The market structure is monopolistic competition, and firms are symmetric within countries (in Section 2.3 I demonstrate the the predictions of the model are robust to the inclusion of firm heterogeneity).

Demand. Preferences across categories are described by a Cobb-Douglas utility aggregator. Specifically, consumers in country i maximize the following utility function

$$U_i = \Pi_{z=1}^{Z} \left(Q_{i,z}\right)^{\eta_z} \ ,$$

where $\sum_z \eta_z = 1$, and $Q_{i,z}$ denotes the quantity consumed of the composite category-z good such that[2]

$$Q_{i,z} = \left[\sum_{j=1}^{N} M_j \left(\alpha_{j,z} q_{ji,z}\right)^{\rho_z}\right]^{\frac{1}{\rho_z}} \ ,$$

where $q_{ji,z}$ denotes the quantity consumed of a typical firm variety exported from country j to market i in category z, and M_j denotes the total mass of firms in country j. Parameter $\alpha_{j,z}$ is an exporter-category fixed effect that reflects the category-specific quality of country j varieties. The above utility specification imposes that quality and quantity are isomorphic—i.e., across all sectors, an increase in quality is equivalent to and increase in consumption quantity. Letting $p_{ji,z}$ denote the price of country j varieties exported to market i in category z, the demand for a given firm variety will be

$$x_{ji,z} \equiv p_{ji,z} q_{ji,z} = \left(\frac{p_{ji,z}/\alpha_{j,z}}{P_{i,z}}\right)^{1-\sigma_z} \eta_z E_i,$$

[2]In the above utility function quantity, q, and quality, α, are isomorphic. In fact α could be interpreted as productivity in the standard gravity framework—see Melitz (2003), Chaney (2008), and Kugler and Verhoogen (2012) for models featuring isomorphism between quality and quality.

where $\sigma_z \equiv 1/(1-\rho_z)$; $P_{i,z} = \left[\sum_{j=1}^{N} M_j \left(\alpha_{j,z} p_{ji,z}\right)^{1-\sigma_z}\right]^{\frac{1}{1-\sigma_z}}$ denotes the price index of market i in category z; and $E_i = w_i L_i$ denotes total expenditure in country i, with $E_{i,z} = \eta_z E_i$ denoting expenditure on category z.

Supply. The cost function is linear and uniform across countries and categories. In particular, the variable cost of production and transportation from country j to i is $c_{ji,z}(q) = \tau_{ji} w_j q$, and the cost of entry in country j is $w_j f^e$. Given the market structure, firms charge a constant markup over marginal cost: $p_{ji,z} = \frac{\sigma_z}{\sigma_z - 1} \tau_{ji} w_j$.

Equilibrium. Given wages and the mass of firms, bilateral trade values are uniquely pinned down. In particular,

$$X_{ji,z} \equiv M_j x_{ji,z} = \frac{M_j \left(\tau_{ji} w_j / \alpha_{j,z}\right)^{1-\sigma_z}}{\sum_k M_k \left(\tau_{ki} w_k / \alpha_{k,z}\right)^{1-\sigma_z}} \eta_z w_i L_i. \tag{1}$$

Equilibrium is a vector of wages $\{w_i\}_i$ and mass of firms $\{M_i\}_i$ that satisfy the balanced trade (BT) and free entry (FE) conditions:

$$\begin{cases} w_j L_j = \sum_{z=1}^{Z} \sum_{i=1}^{N} X_{ji,z} & \text{BT} \\ w_j f^e M_j = \sum_{i=1}^{N} \sum_{z=1}^{Z} \frac{X_{ji,z}}{\sigma_z} & \text{FE} \end{cases}$$

In the above framework, the assumption that firms operate in multiple categories is adopted only in the interest of clarity. The arguments that follow do not hinge on this assumption, and apply to an alternative environment where firms are single product, with each category featuring a category-specific mass of firms—namely, $M_{i,z}$.

The standard gravity equation (Equation 1) highlights a basic distinction between the various product categories, and informs us about the patterns of comparative advantage. In particular, considering Equation 1, whereas trade costs, τ_{ji}, are uniform across tradable product categories, the *effective* trade cost, $\tau_{ji}^{\sigma_z - 1}$, is systematically higher in high-σ categories. That being the case, one could label the high-σ (low-σ) categories as being less tradable (more tradable).

In equilibrium, two distinct channels govern comparative advantage across categories: (i) the across category variation in exporter fixed effects, $\alpha_{j,z}$, and (ii) the across category variation in the trade elasticity, σ_z. The former channel is well understood and vastly studied in the trade literature (see Costinot, Donaldson, and Komunjer (2012)). Therefore, by imposing the following restriction, I purposely abstract for the former channel and focus on the latter.

Assumption 1. *Exporter fixed effects are uniform across categories:* $\alpha_{j,z} = \alpha_{j,z'} = \alpha_j$.

Applying the above assumption and manipulating Equation 1, implies the following, which describes the equilibrium patterns of *revealed* comparative advantage:

$$\frac{X_{ji,z}/X_{ji,k}}{X_{ni,z}/X_{ni,k}} = \left(\frac{\tau_{ji} w_j/\alpha_j}{\tau_{ni} w_n/\alpha_n}\right)^{\sigma_k - \sigma_z}.$$

Three predictions follow from the above equation. Namely, all else equal,

i. High-α countries have higher income levels (w), a lower effective wage (w/α) and, therefore, a comparative advantage in high-σ sectors.

ii. High-τ countries have comparative advantage in low-σ categories.

iii. The relationship between the trade elasticity, σ, and price is weak and disappears with the introduction of firm heterogeneity (Chaney (2008)). Hence, patterns of specialization across low- and high-σ categories are *uninformative* about the price structure of exports.

Patterns (i) and (ii) have direct implications about changes in trade composition in response to trade liberalization. In particular, consider and environment with uniform trade costs across country pairs and categories, and let $\lambda_{ii,z} \equiv X_{ii,z}/E_{i,z}$ denote the domestic expenditure share of country i in category z. Given that $\frac{\partial \ln \lambda_{ii,z}}{\partial \ln \tau} = (\sigma_z - 1)\left[1 - \lambda_{ii,z}\right]$, it follows immediately that, at the global level, a decline in trade costs would expand trade relatively more in high-σ categories. As a result, given that high-income (high-α) countries have a comparative advantage in low-σ categories, trade liberalization would expand their role in global trade.

The standard gravity framework also takes a restrictive parametric stance with respect to the demand structure. First, allowing for expenditure shares to vary

across countries involves assigning Z free moving parameters to each of the N countries in the sample (these parameters would correspond to the Cobb-Douglas expenditure shares). Even then, national expenditure shares across categories are invariant to a reduction in trade costs. This restrictive feature hinders both in the in-sample and out-of-sample predictive power of the standard model—an issue I will come back to in Section 3.

2.2 The Amended Gravity Model

The amended gravity model departs from the standard model in two assumptions: (i) it features flexible *cross-elasticity effects* (i.e., CES rather than Cobb-Douglass preferences across categories), and (ii) it relaxes the *quality-quantity isomorphism*. In particular, preferences across categories are described the following CES utility function

$$U_i = \left(\sum_z Q_{i,z}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} ,$$

where η denotes the elasticity of substitution across categories, and $Q_{i,z}$ is given by

$$Q_{i,z} = \left[\sum_{j=1}^{N} M_j \left(\alpha_{j,z}^{1-\rho_z} q_{ji,z}^{\rho_z} \right) \right]^{\frac{1}{\rho_z}} . \tag{2}$$

The above demand structure relaxes the quality-quantity isomorphism, allowing for the relative importance of product quality to vary across categories. In addition to enhancing macro-level predictions, the breakdown of the quality-quantity isomorphism is motivated by micro-level evidence in Baldwin and Ito (2008), Rodrik (1994), and Bils and Klenow (2001).[3]

[3]Isomorphism between quantity and quality implies that the relative importance of product quality to price is uniform across goods and industries. Several studies have empirically rejected this assertion. Baldwin and Ito (2008) and Aiginger (1997) show that some industries are characterized by quality-competition, whereas others operate on the basis of price competition. Similarly, Rodrik (1994) argues that some goods are more quality-intensive than others, and that this feature is quantitatively important in explaining growth patterns across developing countries. Fan, Li, and Yeaple (2015) show that quality upgrading and tariff reductions have differential effects on revenues across different products. Bils and Klenow (2001) show that the elasticity of demand with respect to product quality and price could diverge depending on income and the product class. Additionally, in environments with multiple categories of goods, the quality-quantity isomorphism implies that high-quality suppliers (like low-cost suppliers) sell relatively more in high-

On the supply side, the amended model is identical to the standard model. In particular, labor is the only factor of production, the cost function is linear, and prices exhibit a constant category-specific markup over marginal cost: $p_{ji,z} = \frac{\sigma_z}{\sigma_z - 1}\tau_{ji,z} w_j$. Altogether, given wages, w_j, and the mass of firms, M_j, bilateral trade values are uniquely pinned down by the following equation:

$$X_{ji,z} \equiv M_j x_{ji,z} = \frac{M_j \alpha_{j,z} \left(\tau_{ji} w_j\right)^{1-\sigma_z}}{\sum_k M_k \alpha_{k,z} \left(\tau_{ki} w_k\right)^{1-\sigma_z}} \left(\frac{P_{i,z}}{P_i}\right)^{1-\eta} E_i, \tag{3}$$

where $P_{i,z} = \left(\sum_{j=1}^{N} M_j \alpha_{j,z} p_{ji,z}^{1-\sigma_z}\right)^{\frac{1}{1-\sigma_z}}$ and $P_i = \left(\sum_{z=1}^{Z} P_{i,z}^{1-\eta}\right)^{\frac{1}{1-\eta}}$ denote the aggregate and category-specific price indexes in country i; $E_i = w_i L_i$ denotes total expenditure in country i, with $E_{i,z} = \left(\frac{P_{i,z}}{P_i}\right)^{1-\eta} E_i$ denoting expenditure on category z. As in the standard model, equilibrium is a vector of wages $\{w_i\}_i$ and mass of firms $\{M_i\}_i$ that satisfy the balanced trade (BT) and free entry (FE) conditions.

Applying Assumption 1, and manipulating the gravity equation implies the following relationship, which describes the variation in trade flows across exporters and categories:

$$\frac{X_{ji,z}/X_{ji,k}}{X_{ni,z}/X_{ni,k}} = \left(\frac{\tau_{ji} w_j}{\tau_{ni} w_n}\right)^{\sigma_k - \sigma_z}.$$

As with the standard model, the equilibrium structure of trade can be characterized using the above equation. In particular, in a cross section of countries, the following three patterns emerge:

i. High-α countries, which pay higher wages (w), have a comparative advantage in low-σ sectors. In particular, all else equal, $w_n > w_s$, $\sigma_L < \sigma_H \implies X_{ni,L}/X_{ni,H} > X_{si,L}/X_{si,H}$

ii. High-τ countries have comparative advantage in low-σ categories. In particular, all else equal, $\tau_{ni} > \tau_{si}$, $\sigma_L < \sigma_H \implies X_{ni,L}/X_{ni,H} > X_{si,L}/X_{si,H}$.

price-elasticity categories, which contradicts the findings of Hausman, Leonard, and Zona (1994), Berry, Levinsohn, and Pakes (1995), and Goldberg (1995) — these studies find that within a narrowly defined markets, high-quality suppliers face a lower price elasticity. Finally, in the context of trade, several studies including Sutton (2007) and Hallak and Sivadasan (2013) have challenged the isomorphism between quality and productivity. In particular, Hallak and Sivadasan (2013) argue that models with quality-productivity isomorphism explain the *exporter premia*, but fail to account for the *conditional exporter premia*. Similarly, Roberts, Xu, Fan, and Zhang (2012) highlight the distinction between cost-shifters and demand-shifters using firm-level evidence.

iii. The relationship between the trade elasticity, σ, and price level is strong and robust to the introduction of firm heterogeneity or input-output linkages.

Pattern (i) is consistent with the observation that rich countries have higher value-added exports within manufacturing industries (Johnson and Noguera (2012)), and aligns with micro-level evidence (see Appendix A). Moreover, patterns (i)-(iii) give rise to some attractive equilibrium outcomes, which I will highlight below.

First, the structure of consumption may diverge across low- and high-wage countries, whereby high-α (high-wage) countries spend relatively more on low-σ (more-tradable) categories. To be more specific, the comparative advantage of high-α countries in low-σ categories translates into a lower autarky relative *price index* for these categories. In particular, consider countries n and s that differ only in α: $\alpha_n > \alpha_s$. As shown in Appendix B, it follows that the autarky relative price of low-σcategories is lower in country n:

$$\begin{cases} w_n > w_s \\ \sigma_H > \sigma_L \end{cases} \implies \left(\frac{P_{n,L}}{P_{n,H}}\right)^{\mathrm{A}} < \left(\frac{P_{s,L}}{P_{s,H}}\right)^{\mathrm{A}}.$$

Opening to trade leads to incomplete price convergence, given that trade is possible but costly. In particular, in the trade equilibrium, low-σ categories remain cheaper in high-wage countries and attract a higher share of expenditure. Considering countries n and s, this result can be stated as

$$\sigma_H > \sigma_L \implies \left(\frac{P_{n,L}}{P_{n,H}}\right)^{\mathrm{A}} < \frac{P_{n,L}}{P_{n,H}} < \frac{P_{s,L}}{P_{s,H}} < \left(\frac{P_{s,L}}{P_{s,H}}\right)^{\mathrm{A}} \implies \frac{E_{n.L}}{E_{n,H}} > \frac{E_{s,L}}{E_{s,H}}.$$

By accounting for the cross-national variation in expenditure shares, the amended model performs better than the standard model in matching ***in-sample bilateral trade shares***, when fitted to cross-sectional trade data. The improvement concerns the model's ability to correctly distinguish between North-North and South-South trade. In particular, high-wage countries spend relatively more on, and have a comparative advantage in more-tradable (low-σ) categories, and therefore engage more intensively in North-North trade (two-way, intra-category trade with each other). Expenditure in low-wage countries, by contrast, is concentrated primarily on less-tradable (high-σ) categories, which are sourced predominantly from local

suppliers. Hence, poor countries engage relatively less in South-South trade (two-way, intra-category trade with other poor countries). Section 3 shows how these predictions align with actual data, enhancing the amended model's in-sample predictive power.

The second improvement concerns the model's ability to reproduce ***the gravity of unit prices***—namely, the positive relationship between export price levels, bilateral distance, and exporter income. The geography of export prices is governed by the the revealed comparative advantage of high-τ suppliers in low-σ categories. This pattern gives rise to a systematic, positive relationship between bilateral distance and export price level, which is reminiscent of the celebrated "Washington apples" effect.[4] To be specific, consider the average price of exports from country j to market i: $\bar{p}_j = \sum_z \frac{\sigma_z}{\sigma_z - 1} \frac{X_{ji,z}}{X_{ji}}$. All else the same, the average export price level increases with bilateral trade costs. In particular,

$$\frac{\partial \ln \bar{p}_{ji}}{\partial \ln \tau_{ji}} \approx \frac{1}{\bar{p}_{ji}} \left(\sum_z \sigma_z \left(1 - \frac{\bar{\sigma} - 1}{\sigma_z - 1} \right) \frac{X_{ji,z}}{X_{ji}} \right) > 0,$$

where $\bar{\sigma} - 1 \equiv \sum_z (\sigma_z - 1) \frac{X_{ji,z}}{X_{ji}}$. Importantly, unlike in the standard model, the positive price-trade cost elasticity is robust to the introduction of firm heterogeneity. Specifically, present firm heterogeneity, the markup in category z remains positively and systematically correlated with the trade elasticity, keeping the above result intact (see Section 2.3).[5]

Arguing along similar lines, the revealed comparative advantage of high-wage (high-α) countries in low-σ categories, gives rise to a systematic relationship between income per capita and export price levels. In particular, given that $\frac{\partial \ln w_j}{\partial \ln \alpha_j} > 0$

[4] If one decomposes value into quantity and price, export-quantity decreases with distance whereas export-price increases (Bernard, Jensen, Redding, and Schott (2007)). The positive relation between export price and bilateral distance is a well-documented regularity know as the "Washington apples" effect. Surprisingly, despite being one of the best-documented regularities in trade, the "Washington apples" effect is inconsistent with all mainstream gravity models (see Baldwin and Harrigan (2011)). The standard explanation for the effect is based on *additive* (non-iceberg) trade costs, and is due to Alchian and Allen (1983).

[5] A real world example that corresponds to this effect, is auto exports from Europe. Europe exports the luxury, high-markup brands (e.g., Audi, BMW, Volvo) to the US, whereas the economy, low-markup brands (Opel, Renault, Peugeot) are not exported to the US market, but sold mostly in the local European market.

the following relationship follows immediately

$$\frac{\partial \ln \bar{p}_{ji}}{\partial \ln \alpha_j} \approx \frac{\partial \ln w_j}{\partial \ln \alpha_j} \left\{ 1 + \frac{1}{\bar{p}_{ji}} \sum_z \sigma_z \left(1 - \frac{\bar{\sigma} - 1}{\sigma_z - 1} \right) \frac{X_{ji,z}}{X_{ji}} \right\} > 0,$$

Again, the above prediction is robust to the inclusion of firm heterogeneity or input-output linkages. Furthermore, it is distinct from standard *vertical specialization* arguments where high-income countries specialize in high-quality categories. Instead, the above prediction is driven by high-income countries specializing in quality-intensive (low-σ) categories that display higher markup levels.

In addition to characterizing the cross-sectional structure of trade, the amended model delivers sharp predictions regarding changes in trading structure along the course of trade liberalization. Three basic predictions, in particular, stand out:

i. Trade liberalization induces consumption diversification, whereby countries spend relatively more on their comparative disadvantage categories.

ii. Due to *love-of variety* effects, low-σ categories expand relative to high-σ categories in face of trade liberalization (i.e., globally, the share of expenditure on low-σ categories increase).

iii. However, foreign trade shares grow disproportionally faster within high-σ categories than low-σ categories.

Pattern (i) follows from the fact that trade liberalization lowers the relative price index of the comparative disadvantage categories in each market. Pattern (ii) corresponds to the pro-variety effects of trade, where as a result of trade the number of varieties increases uniformly across all categories. Consequently, the share of expenditure increases disproportionally more on low-σ categories, which feature a stronger love-of-variety. Pattern (iii) is a direct consequence of the higher trade elasticity in high-σ categories, whereby a decline of $\hat{\tau} = \tau'/\tau$ in trade costs has an effect on trade shares that is proportional to $\hat{\tau}^{1-\sigma_z}$.

In light of the above predictions, the amended model can replicate the ***out-of-sample variation in trade structure*** in response to trade liberalization. In particular, consider the rise of North-South trade relative to North-North trade—a pattern highlighted in Figure 1 in the Introduction. The amended accounts for this change

as follows. A decline in trade costs triggers two developments. First, high-income countries diversify consumption, and spend relatively more on high-σ categories. Second, trade grows disproportionally more within high-σ categories. Given that low-income countries have a comparative advantage in high-σ categories, these two developments increase the relative importance of North-South to North-North trade.

2.3 Extensions

In the amended model the patterns of specialization and trade transformation hinge on the apparent link between the trade elasticity, the degree of tradability, and markup/price level. In light of Chaney (2008), there is a widespread belief in the literature that this link is rather weak. In this section, I show that this link is in fact robust once the quality-quantity isomorphism is relaxed. To this end, I demonstrate that the predictions of the amended model are robust to the introduction of firm-level heterogeneity or input-output linkages.

Firm-Level Heterogeneity. Below, I present an extension of the amended model where firms are heterogeneous in quality. Preferences across categories and firm varieties are similar to the benchmark model. In particular, $U_i = \left(\sum_z Q_{i,z}^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}$, where

$$Q_{i,z} = \left[\sum_{j=1}^{N} \int_{\omega\in\Omega_j} \varphi_\omega^{1-\rho_z} q_{\omega i,z}^{\rho_z} d\omega\right]^{\frac{1}{\rho_z}}.$$

In the above utility function ω indexes a firm, and φ_ω denotes the quality of firm ω. Firms are heterogeneous in quality, which is drawn independently from a country-specific Fréchet distribution:

$$G_i(\varphi) = 1 - \alpha_i \varphi^{-\gamma}.$$

Following Chaney (2008), I focus on a model with restricted entry—i.e., the mass of firms in country i is fixed to M_i. Firms in country j have to pay a local fixed cost $w_i f_{ji}$ to penetrate market i. Within-category bilateral trade values are thus given

by

$$X_{ji,z} = M_j \left(\frac{\sigma_z}{\sigma_z - 1} \frac{\tau_{ji} w_j}{P_{i,z}} \right)^{1-\sigma_z} \left(\int_{\varphi^*_{ji,z}}^{\infty} \varphi dG_j(\varphi) \right) E_{i,z}, \tag{4}$$

where $\varphi^*_{ji,z}$ denotes the category-specific quality cut-off, above which a firm will profitably export from country j to i. $\varphi^*_{ji,z}$ is pinned down by the *zero cut-off profit* condition:

$$\varphi^*_{ji,z} \left(\frac{\sigma_z}{\sigma_z - 1} \frac{\tau_{ji} w_j}{P_{i,z}} \right)^{1-\sigma_z} \frac{E_{i,z}}{\sigma_z} = w_i f_{ji} \implies \varphi^*_{ji,z} = \left(\frac{\sigma_z}{\sigma_z - 1} \frac{\tau_{ji} w_j}{P_{i,z}} \right)^{\sigma_z - 1} \frac{\sigma_z f^e}{E_{i,z}/w_i}.$$

The average quality of country j's exports to market i in category z can, therefore, be calculated as:

$$\left(\int_{\varphi^*_{ji,z}}^{\infty} \varphi dG_j(\varphi) \right) = \frac{\gamma}{\gamma - 1} \left(\varphi^*_{ji,z} \right)^{1-\gamma} = \frac{\gamma}{\gamma - 1} \alpha_j \left(\frac{\sigma_z}{\sigma_z - 1} \frac{\tau_{ji} w_j}{P_{i,z}} \right)^{-(\sigma_z - 1)(\gamma - 1)} \left(\frac{\sigma_z f_{ji}}{E_{i,z}/w_i} \right)^{1-\gamma}.$$

Plugging the above expression into Equation 4 implies

$$X_{ji,z} = \alpha_j M_j \frac{\gamma}{\gamma - 1} \left(\frac{\sigma_z}{\sigma_z - 1} \frac{\tau_{ji} w_j}{P_{i,z}} \right)^{\gamma(1-\sigma_z)} \left(\frac{\sigma_z f_{ji}}{E_{i,z}/w_i} \right)^{1-\gamma} X_{i,z}.$$

The above equation combined with the market clearing condition delivers the following gravity equation

$$X_{ji,z} = \frac{\alpha_j M_j \left(\tau_{ji} w_j \right)^{\gamma(1-\sigma_z)} f_{ji}^{1-\gamma}}{\sum_{k=1}^{N} \alpha_k M_k \left(\tau_{ki} w_k \right)^{\gamma(1-\sigma_z)} f_{ki}^{1-\gamma}} E_{i,z}. \tag{5}$$

The above gravity equation, like the benchmark case, implies that high-markup (low-σ) categories are subject to a lower trade elasticity, $\gamma(\sigma - 1)$, and are thus more tradable. Furthermore, like the benchmark case, Equation 5 implies that high-wage countries have a revealed comparative advantage in low-σ (more-tradable, high-markup) product categories. In particular,

$$\frac{X_{ni,l}/X_{ni,h}}{X_{si,l}/X_{si,h}} = \left(\frac{\tau_{ni} w_n}{\tau_{si} w_s} \right)^{\gamma(\sigma_h - \sigma_l)}.$$

Provided that $\gamma > 1$, the above equation implies that patterns of revealed compar-

ative advantage are intensified with the introduction of firm heterogeneity. All the equilibrium outcomes highlighted in the benchmark case will then follow immediately from the above equation.

Input-Output Linkages. The introduction of input-output linkages slightly weakens, but does not eliminate the patterns of specialization described in the benchmark model. To demonstrate this, consider an extension of the amended model where production combines an aggregate intermediate input with labor, such that the variable cost function becomes $c_{ji,z}(q) = \tau_{ji} w_i^{\zeta} P_i^{1-\zeta} q$, where $0 < \zeta < 1$ denotes the share of labor in production. Taking the same steps as before, the gravity equation in category z can be written as

$$X_{ji,z} = \frac{M_j \alpha_{j,z} \left(\tau_{ji} w_j^{\zeta} P_j^{1-\zeta} \right)^{1-\sigma_z}}{\sum_k M_k \alpha_{k,z} \left(\tau_{ki} w_k^{\zeta} P_k^{1-\zeta} \right)^{1-\sigma_z}} \left(\frac{P_{i,z}}{P_i} \right)^{1-\eta} E_i,$$

where $E_i = \frac{w_i L_i}{\zeta}$ denotes total expenditure in country i. Manipulating the above gravity equation we will arrive at

$$\frac{X_{ni,l}/X_{ni,h}}{X_{si,l}/X_{si,h}} = \left(\frac{\tau_{ni} w_n^{\zeta} P_n^{1-\zeta}}{\tau_{si} w_s^{\zeta} P_s^{1-\zeta}} \right)^{\sigma_h - \sigma_l}.$$

Under free trade ($\tau_{ji} = 1$ and $P_i = P_j$ for all i, j) the above equation further reduces to

$$\frac{X_{ni,l}/X_{ni,h}}{X_{si,l}/X_{si,h}} = \left(\frac{w_n}{w_s} \right)^{\zeta(\sigma_h - \sigma_l)}.$$

Hence, given that $0 < \zeta < 1$, high-wage countries maintain a revealed comparative advantage in low-σ categories, but these patterns are weaker than in the benchmark case. An increase in trade costs, however, intensifies these patterns as it causes national price indexes and production costs to further diverge across low- and high-wage exporters.

3 Mapping the Model to Data

In this section, I fit the amended model to data, and compare its predictive power to the standard gravity model. The amended model delivers distinct predictions about (i) the variation in trade values at the national level and (ii) the variation in export price levels at the industry level. The parameters of the model can, therefore, be identified using either cross-national variation in trade values or spatial variation in export price levels. Since data on trade values are less noisy, I adopt the former approach that involves fitting the model to bilateral trade values. In particular, I match aggregate trade values (which are available for a wide range of countries) by treating the economy as one integrated industry consisting of two categories of goods: $z \in \{H, L\}$—this strategy is similar to that of Fieler (2011). I then demonstrate the merits of the model by comparing it to a standard gravity model fitted to the same data.

Alternatively, at the expense of losing coverage in terms of the number of countries, I could estimate the amended model with sectoral trade data. In that case, with data on K sectors and N countries (i.e., $N \times N \times K$ data points) I can estimate the structural parameters pertaining to an economy with $2 \times K$ categories of goods. The arguments presented in this paper nonetheless remain qualitatively the same irrespective of how many categories of goods are included in the analysis. Hence, facing a trade-off between including more countries versus more categories, I opt for a sample of more countries. Below, I first describe my estimation strategy, then I present the estimations results and discuss the implications.

Data . I use data on bilateral merchandise trade flows in 2000 from the U.N. COMTRADE database (Comtrade (2010)). The data on population size and GDP are from the World Bank database (World-Bank (2012)). The sample consists of the 100 largest economies (in terms of real GDP), which account for more than 95% of world trade in 2000. Data corresponding to bilateral variables (namely, distance, common official language, and borders) are compiled by Mayer and Zignago (2011).

3.1 Estimation Strategy

The amended model is characterized by structural parameters η (the elasticity of substitution between categories H and L), σ_H, σ_L, a vector of country of origin fixed effect $\{\alpha_i\}_i$, and a matrix of trade costs $\{\tau_{ji}\}_{j,i}$. The standard gravity model features the same set of parameters except that η adopts a different interoperation, and corresponds to the share of income spent on category H.

I use the cross sectional variation in aggregate bilateral trade values and income per capita levels to estimate the parameters of the model. The estimation is conducted along the following steps. Given the mass of firms $\{M_i\}_i$, population size $\{L_i\}_i$, wages $\{w_i\}_i$, exporter fixed effects $\boldsymbol{\alpha} \equiv \{\alpha_i\}_i$, iceberg trade costs $\boldsymbol{\tau} \equiv \{\tau_{ji}\}_{j,i}$, and parameters σ_L, σ_H, and η, I can calculate the aggregate export flows from country j to i as[6]

$$X_{ji} = X_{ji,H} + X_{ji,L} \,, \tag{6}$$

where $X_{ji,H}$ and $X_{ji,L}$ are given by Equation 3 (or Equation 1 in the case of the standard model). I use data on populations size (L_i) and wage levels (w_i) to (i) solve for a vector of exporter fixed effects ($\boldsymbol{\alpha}$) that are consistent with the balanced trade condition; (ii) solve for the mass of firms M_j using the free entry condition; and (iii) estimate $\boldsymbol{\tau}$, σ_L, σ_H, and η. Below, I formally describe the estimation procedure:

i. I parametrize the iceberg trade costs as follows:

$$\tau_{ji} = 1 + \left[\kappa_{\text{const}} + \kappa_{\text{dist}}\text{dist}_{ji}\right] \kappa_{\text{border}}\kappa_{\text{lang}}\kappa_{\text{agreement}}$$

where dist_{ji} denotes the distance (in thousands of kilometers) between countries j and i. κ_{border}, is one if countries do not share a border, and an estimated parameter otherwise.[7] Similarly, $\kappa_{\text{agreement}}$ and κ_{lang} are one if a country pair do not have a trade agreement or a common-language, and estimated otherwise. Altogether, $\boldsymbol{\kappa} \equiv \{\kappa_{\text{border}}, \kappa_{\text{lang}}, \kappa_{\text{agreement}}, \kappa_{\text{const}}, \kappa_{\text{dist}}\}$ denotes the vector of parameters describing the iceberg trade costs. For a given $\boldsymbol{\kappa}$, and data on distance, trade agreements, common-language and borders, I can construct a matrix of iceberg trade costs.

[6] The entry cost parameter, f^e, governs the scale of entry and is normalized to one. The normalization does not affect trade values, as it normalizes the mass of national firms.

[7] For example, if κ_{border} is, say, 0.9, sharing a border reduces $\tau_{ji} - 1$ by 10%.

ii. Given parameters $\{\boldsymbol{\kappa}, \boldsymbol{\alpha}, \sigma_L, \sigma_H, \eta\}$, plus data ($\mathbf{D}$) on wage, population, distance, trade agreements, common languages and borders I can solve for the mass of firms using the *free entry condition*:

$$M_j = M_j(\mathbf{D}; \boldsymbol{\kappa}, \boldsymbol{\alpha}, \sigma_L, \sigma_H, \eta).$$

iii. Given $\mathbf{M} \equiv \{M_j\}_j$ from the previous step, parameters $\{\boldsymbol{\kappa}, \sigma_L, \sigma_H, \eta\}$, and data ($\mathbf{D}$), I solve for a vector of exporter fixed effects, $\boldsymbol{\alpha}$, that satisfy the *balanced trade* condition:

$$\alpha_j = \alpha_j(\mathbf{D}; \mathbf{M}, \boldsymbol{\kappa}, \sigma_L, \sigma_H, \eta).$$

That is, α_j is chosen so that the market clearing wage equals data on GDP per capita.

iv. For any set of parameters, $\{\boldsymbol{\kappa}, \sigma_L, \sigma_H, \eta\}$, and data, $\mathbf{D}$, I iterate over steps *ii* and *iii* to find an implicit solution for $\{\alpha_j\}_j$ and $\{M_j\}_j$. Using the implicit solution, I calculate bilateral trade flows, X_{ji}, from Equation 6, and the matrix of trade shares as $\lambda_{ji} = \frac{X_{ji}}{E_i}$. The gravity equation in stochastic form becomes

$$\ln \lambda_{ji} = g(\mathbf{D}; \boldsymbol{\kappa}, \sigma_L, \sigma_H, \eta) + \varepsilon_{ji} \tag{7}$$

The above equation indicates that trade shares (λ_{ji}) are a function of data, $\mathbf{D}$, the estimated parameters, $\{\kappa_{\text{border}}, \kappa_{\text{lang}}, \kappa_{\text{agreement}}, \kappa_{\text{const}}, \kappa_{\text{dist}}, \sigma_L, \sigma_H, \eta\}$, and the error term ε_{ji}. I estimate Equation 7 by minimizing the residual sum of squares (Non-linear Least Squares (NLLS)). Anderson and Van Wincoop (2003) show that the NLLS estimator is unbiased if ε is uncorrelated with the derivative of $g(.)$ with respect to $\mathbf{D}$, which is the case if ε represents measurement errors.

Identification of parameters. The trade cost parameters, $\boldsymbol{\kappa}$, are identified based on the spatial variation in bilateral trade values. The category-specific trade elasticities are not jointly identified from the trade cost parameters. However, if we set $\sigma_H = 6$, we can separately identify σ_L. In particular, the spread $\frac{\sigma_H}{\sigma_L}$ governs the degree of international production specialization across categories H and L, and

hence regulates the cross-national variation in the distance elasticity of exports. Parameter η governs the effect of cross-national price differences on cross-national consumption differences. Provided that expenditure shares on low- versus high-σ categories determine trading intensities, η is identified using the cross-national variation in trade-to-GDP ratios.

3.2 Estimation Results

The estimation results are presented in Table 1. The first column reports the estimation results for the amended model. Column two reports estimation results corresponding to the standard gravity model. Expectedly, the fit of the standard gravity model is relatively poor, given that both low and high-wage countries are included in the analysis. One could potentially improve the in-sample fit of the standard model by introducing importer fixed effects, which amounts to estimating 100 additional free parameters. The amended model, meanwhile, includes the same number of free parameters, but delivers an R^2 that is 25 percent higher than the standard model.

The superior fit of the amended model reflects its ability to match two empirically important margins in the data:

i. ***Income per capita*** $\times$ ***trade intensity*****:** Factually, South-South trade (two-way trade between poor countries) is conducted less intensively than North-North trade. The standard model model cannot capture this pattern because (i) it predicts that high-wage countries have a comparative advantage in the high-σ (less-tradable) category, and (ii) it imposes that the expenditure structure is uniform across countries. The amended model, however, predicts that high-wage countries have a comparative advantage in and spend relatively more on the low-σ (more-tradable) category. As a result, North-North trade, which involves more-tradable goods, is conducted more intensively than South-South trade, which involves less-tradable goods—Figure 2 illustrates the performance of the two model with regards to matching the underlying composition of trade.[8] Relatedly, the standard model counterfac-

[8]North consists of the 21-richest countries in the sample and has roughly the same GDP as the South

Table 1: *Estimation Results*

Parameters	**Amended Model**	**Standard Model**
$\frac{\sigma_H}{\sigma_L}$	1.70 (0.013)	1.96 (0.018)
η	2.11 (0.021)	0.93 (0.002)
κ_{const}	4.10 (0.037)	3.08 (0.063)
κ_{dist}	0.32 (0.005)	0.82 (0.026)
κ_{border}	0.51 (0.010)	0.83 (0.021)
κ_{lang}	0.87 (0.008)	0.68 (0.010)
$\kappa_{\text{agreement}}$	0.66 (0.014)	0.98 (0.023)
R^2 (*Goodness of fit*)	0.44	0.35

Note: η in the amended model corresponds to the cross-category elasticity of substitution, whereas in the standard model it represents the expenditure share on category H. Standard errors are reported in parenthesis.

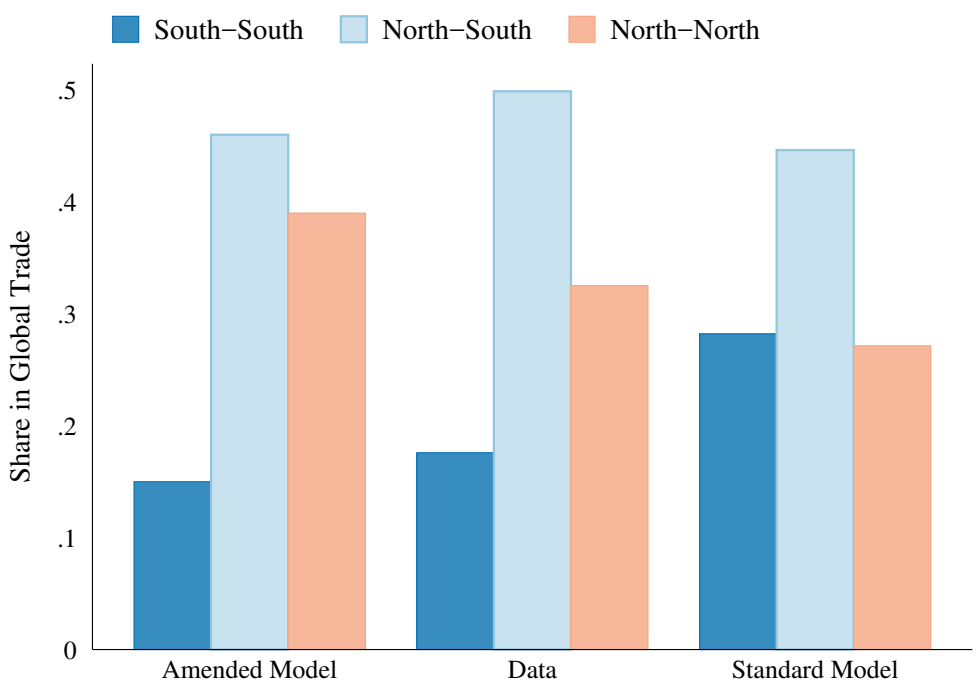
tually predicts higher trade-to-GDP levels in low-wage countries, whereas the amended model correctly captures the positive relationship between per capita income and trade-to-GDP levels: $\frac{\text{N-N + N-S}}{\text{GDP}_N} > \frac{\text{S-S + N-S}}{\text{GDP}_S}$ —see Figure 7.

ii. ***Income per capita*** $\times$ ***trade elasticity*****:** A basic analysis of the data reveals that export flows from poor countries are more sensitive to distance. To formally illustrate this pattern, I run a gravity regression on my sample of 100 countries allowing for an interaction between the exporter's income per capita and distance. Namely,

$$\ln X_{ji} = \left(\underset{(0.15)}{-3.26} + \underset{(0.02)}{0.20} \ln w_j \right) \ln \text{DIST}_{ji} + S_j + M_i + \epsilon_{ji},$$

where S_j and M_i denote exporter and importer fixed effects, with the robust standard errors reported in parentheses. The regression result indicates that export flows from rich countries are significantly less sensitive to distance. In fact, this effect is not limited to the present data set. Disdier and Head (2008) show that the distance elasticity has increased (over-time) with the increased involvement of low-wage countries in trade. The amended model accommodates this pattern by predicting that high-wage countries specialize in and export relatively more of the low-σcategory, which by construction is less sensitive to distance. The standard model, by contrast, delivers the opposite prediction.

Figure 2: *The predicted trade composition versus data.*



Note: The North corresponds to the 21 richest countries in the sample.

3.3 Out-of-sample Predictive Power

As a next step, I compare the out-of-sample predictive power of the two models. The out of sample performance of the standard gravity model has been called

into question by several studies. Specifically, a standard gravity model fitted to cross-sectional trade values performs poorly in predicting both the out-of-sample variation in trade values (Lai and Trefler (2002)) and the spatial variation in export price levels (Baldwin and Harrigan (2011)). Theoretically, the amended model displays improved out-of-sample predictive power on both fronts. However, given the nature of my quantitative exercise (which involves aggregate trade values) I focus on the model's improved predictive power with respect to the out-of-sample variation in trade values.

To asses out-of-sample performance, I turn to one of the most remarkable transformations in international trade. Starting in the 1980s, North-South trade grew in relative importance and, in less than two decades, overtook North-North trade as the most dominant form of trade. This transformation is highlighted extensively in Krugman (2009) and Hanson (2012). What makes this transformation notable is that (i) it coincides with the (weak) divergence of nominal per capita income-levels across rich and poor countries (see Milanovic (2011)), and (ii) trade flows from the South grew close to two-times faster than the size of the Southern economies.[9] The top panel in Figure 3 illustrates this transformation—in 1985 the richest 21 countries were sourcing most of their imports from other rich countries, but this pattern reverses over time and by 2006 more than 60% of rich countries' imports are sourced from poor and middle-income nations.

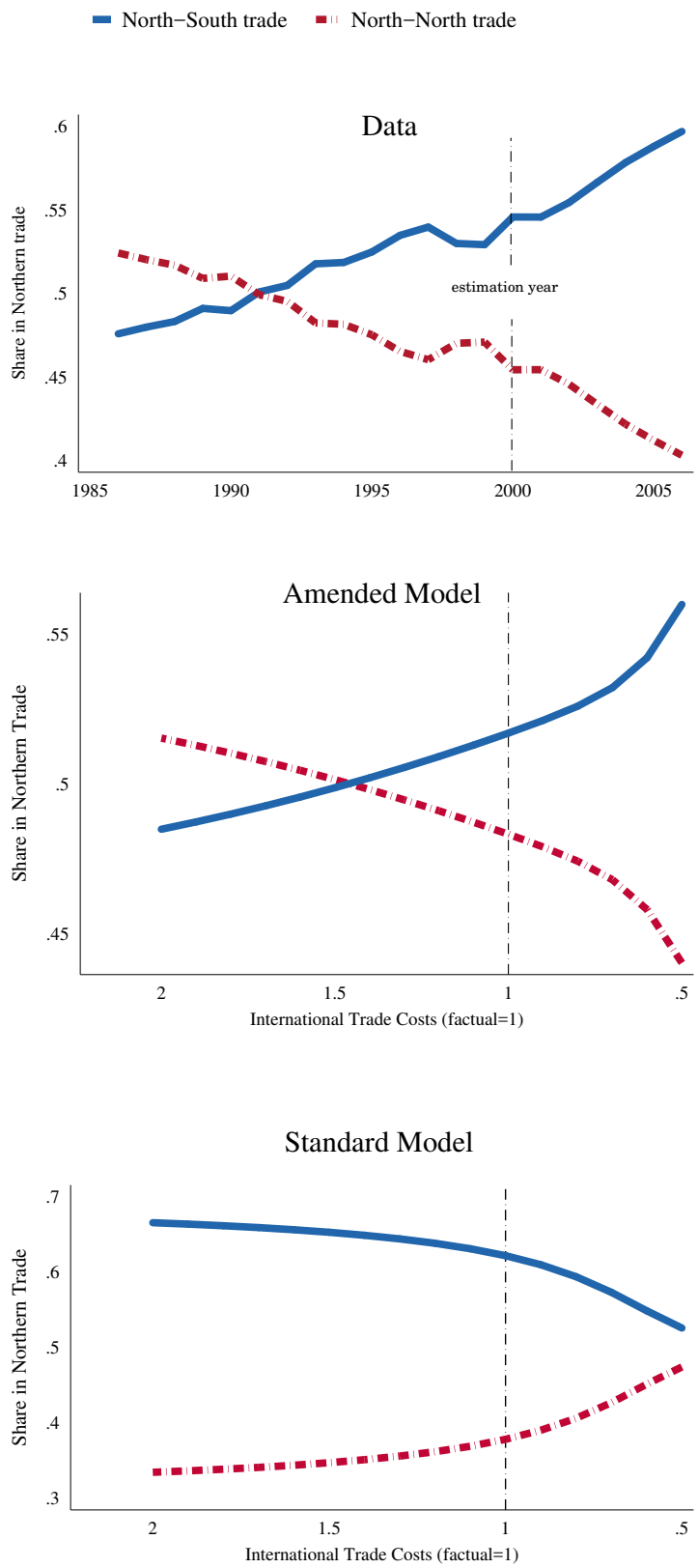
The standard multi-sector gravity model fitted to data from 2000, cannot reproduce this transformation. In the standard model, the structure of global expenditure (across low- and high-σ categories) is invariant to a decline in trade costs. Plus, the decline in trade costs increases trade disproportionally more in the high-σ category in which Northern countries have a comparative advantage. Altogether, as illustrated in Figure 3, these developments slightly increase the relative importance of North-North trade to North-South trade—Figure 3 reports the change in trade structure when trade costs are counterfactually lowered in the estimated model.

The amended model, however, predicts the rise of North-South trade as a natural consequence of trade liberalization. In particular, as noted in Section 2.2, the decline in international trade costs (i) induces countries to spend relatively more

[9]The 2013 WTO world trade report (WTO, 2013) indicates that from 1980 to 2011 the share of developing countries in global trade grew by 45%, while their GDP-share grew by only 27%.

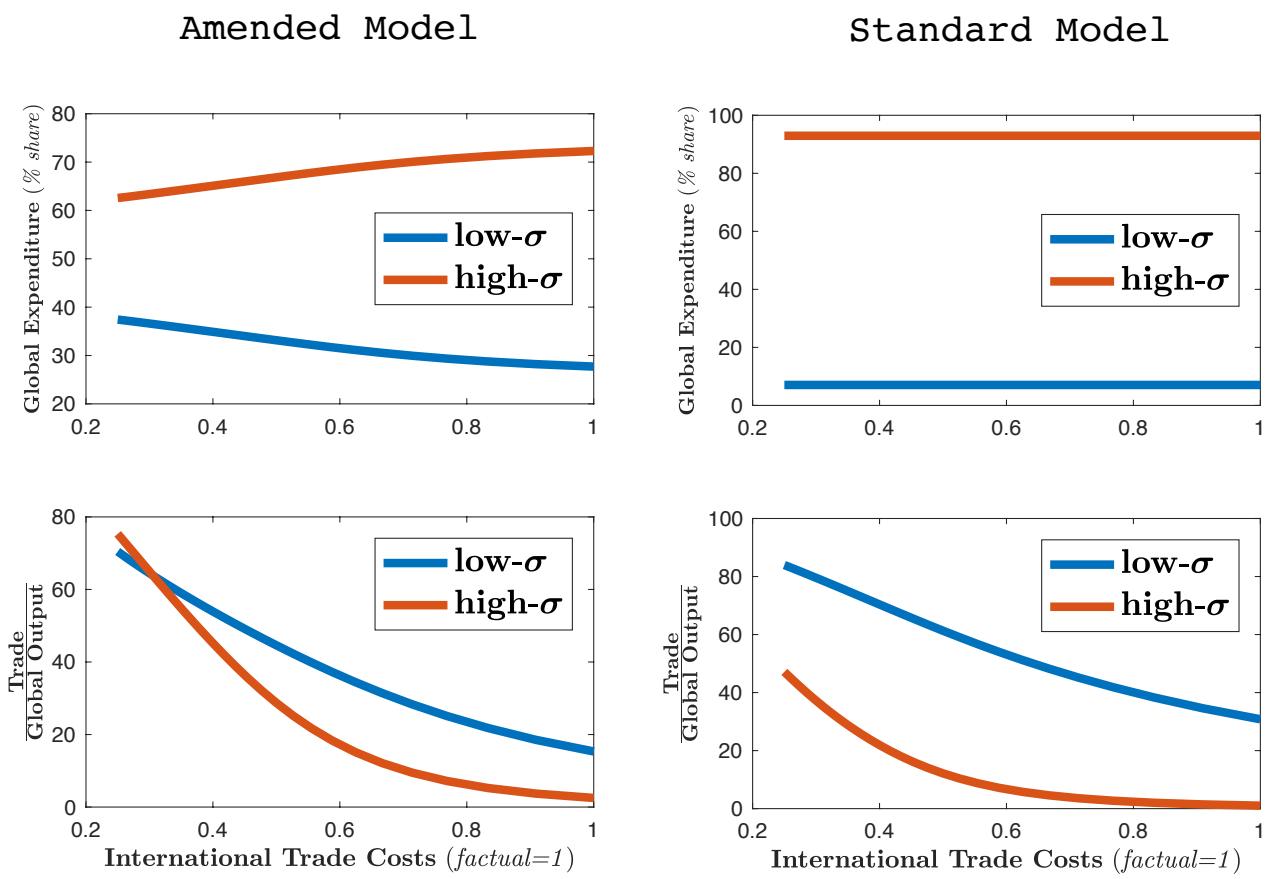
on their comparative disadvantage categories, and (ii) increases trade disproportionally more within the high-σ category in which low-wage countries specialize. Both of these developments (which are illustrated in Figure 4) increase the relative importance of North-South trade to North-North trade in a fashion that mirrors the factual change—see the middle panel of Figure 3.

Figure 3: *Out-of-sample predictive power: New model vs. standard gravity.*



Note: The new model could reproduce the out-of-sample rise of North-South trade relative to North-North trade. The data used to construct the top panel is is from Head et al. (2010)). The figure decomposes the overall trade of the 21 richest countries into: (i) trade with other rich countries (North-North trade) and (ii) trade with middle-income and poor countries (North-South trade). The predictive power of the models are assessed by counter-factually lowering the estimated trade costs to replicate trade liberalization.

Figure 4: *Changes in global trade and expenditure structure in response to trade liberalization.*



Note: This figure displays changes in the underlying structure of trade as trade costs are counterfactually lowered in estimated model—the factual equilibrium corresponds to a global average (normalized) trade cost of 1.

4 Counterfactual Welfare Predictions

In this section, I compare the two models in terms of their counterfactual welfare predictions. In particular, I show that the two models make strikingly different predictions about the effect of trade on cross-national income inequality. In summary, the amended model predicts that trade favors rich nations more than indicated by the standard model.

4.1 Trade Liberalization and Cross-National Income Inequality

Using the estimated models, I can compute the welfare effects of trade liberalization by counterfactually lowering the international trade costs in each model. In the amended model a decline in trade costs has two effects that are highlighted in Figure 4: (i) due to love-of-variety effects, global expenditure on the low-σ category increases, but (ii) within-category trade increases disproportionally more in the high-σ category. Hence, depending on parameter values, trade liberalization may expand or contract the low-σ category in which high-wage countries have a comparative advantage. An expansion of the low-σ product category implies relatively larger gains for high-wage countries, whereas an expansion of the high-σ categories implies relatively larger gains for low-wage countries.

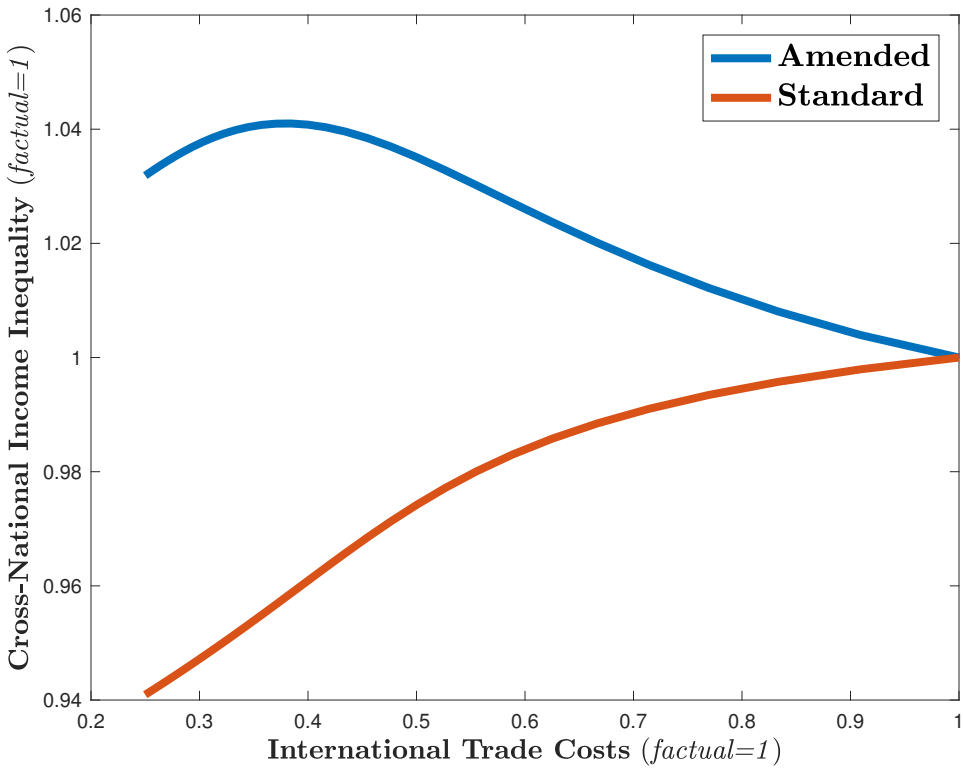
In the estimated model, lowering international trade costs uniformly across all country pairs increases the cross-national dispersion in real per capita income ($\log w_i/P_i$)— see Figure 5. This outcome suggests that, under factual parameter values, trade liberalization expands the low-σ category and contracts the high-σ category. As a consequence, the benefits of trade go disproportionally in the direction of high-wage countries; thus rising the cross-national real income inequality.

The standard model too predicts an expansion of the low-σ category with a decline in trade costs—see right panel of Figure 4. However, in the standard model, the low-σ category is the one in which low-wage countries have a comparative advantage. As a result, the gains from trade liberalization favor low-income nations. Altogether, the standard gravity model predicts that trade lowers the cross-national real income inequality (Figure 5).

The above result is a simple manifestation of how a simple amendment could

vastly alter the counterfactual predictions of the gravity model. The natural question is which prediction should we believe in. The amended model performs better in replicating observable out-of-sample variations, so it arguably delivers more credible predictions with respect to unobservable out-of-sample variations. However, despite its markedly improved out-of-sample predictive power, the amended model remains quite stylized. Hence it should only be viewed as a preliminary step in the direction of attaining better, less-parametric counterfactual predictions.

Figure 5: *Trade liberalization and the cross-national dispersion in real income p/c* ($\log w_i/P_i$)



4.2 The Gains from Trade

Finally, I turn to analyzing the gains from trade relative to autarky, which have been the subject of heated discussion in recent years. Following Arkolakis et al. (2012), it is well understood that the level of the gains from trade are similar across a wide range of single-sector gravity models, which feature distinct underlying micro-foundations. Several papers, including Ossa (2015), have shown that the gains could be substantially larger in in the presence of multiple sectors. Relatedly,

Costinot and Rodríguez-Clare (2014), Kucheryavyy et al. (2016), and Lashkaripour and Lugovskyy (2017) demonstrate that in multi-sector gravity models the cross-national distribution of the gains are highly-sensitive to patterns of specialization—the general assertion is that countries that specialize in high-return sectors (the definition of which varies with the underlying micro-foundation) gain relatively more from trade.

To contribute to the above arguments, I compute the gains from trade relative to autarky using the two estimated models. This involves calculating the changes in real wage w_i/P_i when moving from the factual equilibrium to the counterfactual autarky equilibrium. A summary statistics of the computed gains are provided in Table 2, with country-specific gains reported in Table 4. Overall, the gains from trade are slightly larger in the standard model. This outcome is simply driven by the standard Cobb-Douglas assumption—see Costinot and Rodríguez-Clare (2014) for a through discussion on this matter. The main distinction, however, is that in the amended model the gains from trade are less equally distributed across countries, and the difference between the two models is quite noticeable.

Table 2: *The gains from trade: summary statistics.*

	Mean	Coefficient of variation
Amended Model	4.13%	102.78%
Standard Model	5.70%	56.97%

Note: The gains from trade correspond to percentage changes in real wage when moving from the counter-factual autarky equilibrium to the factual trade equilibrium.

To provide intuition, notice that trade expands and contracts certain product categories or sectors. Hence, depending on patterns of comparative advantage some countries gain relatively more from these adjustments. In the amended model these adjustments (which involve a trade-induced expansion of the low-σ and contraction of the high-σ sectors) are more pronounced than in the standard model. As a result, the gains from trade are less equally distributed, and systematically favor rich countries that have a comparative advantage in the expanding sector.

Relatedly, one should note that the gains from trade will become smaller with the

introduction of non-homothetic preferences à la Fieler (2011).[10] Intuitively, trade always increases the relative price index of the comparative advantage category. To match empirical regularities, non-homotehtic models typically assume that local taste is biased towards the comparative advantage category (Fieler (2011); Atkin (2013)). Through this channel, trade-induced changes in relative price have an adverse effect on welfare that is absent in the amended model.

5 Concluding Remarks

This paper starts with the observation that the standard multi-sector gravity model delivers unsatisfactory predictions with respect to out-of-sample export price levels and trade values. I propose two amendments that improve the out-of-sample predictive power of the gravity framework, while retaining its widely-celebrated parsimony. Importantly, I demonstrate quantitatively that these amendments also modify the cross-national distribution of the gains from trade.

The implications of the amended model, however, span beyond the basic gains from trade predictions. To the extent that quality and productivity are not isomorphic, quality- versus productivity-upgrading have distinct effects on real income in developing countries. In fact, as highlighted in Rodrik (1994), there are strong anecdotal and empirical evidence pointing to these distinctions. The amended gravity model provides a parsimonious framework to study these different industrial policy approaches.

Similarly, the amended model has sharp implications for trade policy. Beshkar and Lashkaripour (2017) demonstrate that introducing flexible cross-elasticity effects (e.g., using a CES rather than a Cobb-Douglas utility aggregator across sectors) lowers the optimal import tax. The present paper estimates a cross-category elasticity of 2.11, whereas existing studies (e.g., Ossa (2014)) often compute optimal tariffs while assuming a unit elasticity, which corresponds to Cobb-Douglas preferences across sectors. The findings in this paper, therefore, suggest that existing estimates of optimal tariffs may be upward-biased, and provide a benchmark for estimating the optimal tariff structure in the presence of cross-elasticity effects.

[10]This point bears special importance given that one could not separately identify the cross-elasticity effects from non-homotehticity in cross-sectional data–see Appendix C.

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Appendix

A Micro-level Evidence

In what follows I contrast the predictions of the amended model with micro-level data. The model predicts that, all else equal, high-income countries export relatively more in low-σ (high-markup) categories. That is, the export-mix from high-income countries should have a higher *markup content* than that of low-income countries. I verify this prediction using product-level US import data.[11] Broda and Weinstein (2006) have estimated the scope for product differentiation (σ_z) for various 10-digit product categories in the data.[12] Using their estimates and product-level import values, I can infer the average markup ($\frac{\sigma_z}{\sigma_z - 1}$) embedded in the exports of a country to the US. Figure 6 plots the markup content of exports against the (average) income per capita of an exporter during the period of 1989 to 2011. The graph supports the prediction that high-income countries export relatively more in high-markup, low-σ product categories. The second test I perform is similar to the one conducted in Hanson and Xiang (2004). Specifically, I look at the variation in Northern to Southern export share across HS10 product categories.[13] Consistent with my theory, I find that Northern export shares are systematically higher in the low-σ (high-markup) HS10 product categories (Table 3).

[11] The product-level US import data is compiled by Schott (2008), and is publicly available

[12] See Soderbery (2015) for updated estimates.

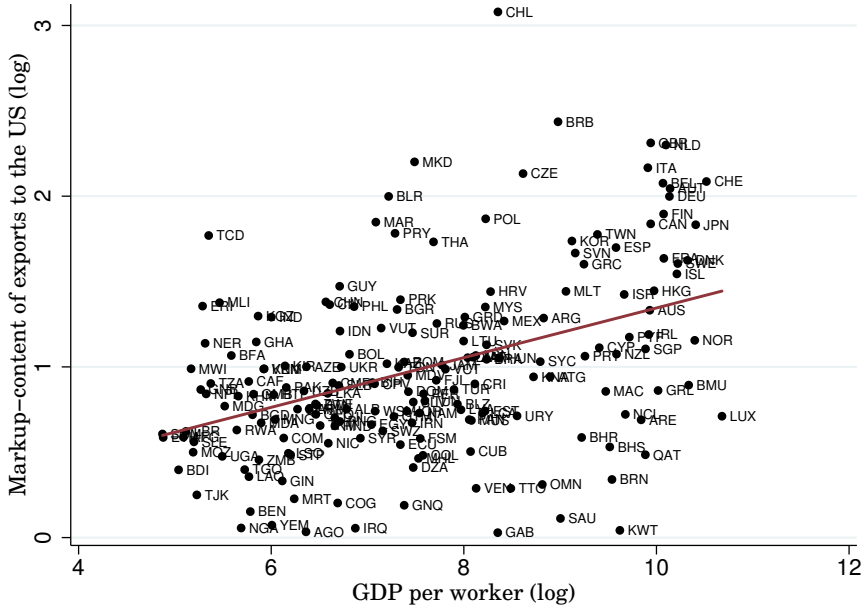
[13] Here, I use the North-South categorization employed in Romalis (2004).

Table 3: *Patterns of specialization in product level import data.*

Dependent variable: $ln\frac{X_{North,z}}{X_{South,z}}$ (North's export share in category z)		
Markup in category z (logs)	0.10***	0.03***
	(0.003)	(0.003)
Constant	0.75***	0.74***
	(0.005)	(0.004)
Observations (product$\times$years)	261,021	252,856
Industry fixed-effect	No	Yes
R^2	0.004	0.004

Note: The table estimates that the export share of high-income countries to the US is significantly higher in high-markup (low-σ) product categories. The high versus low-income categorization is taken from Romalis (2004). The export shares are constructed using 10-digit product-level US import data from 1989 to 2011. The standard errors are reported in parenthesis.

Figure 6: *The composition of exports to the US$\times$Income per capita*



B The Structure of Trade: *North vs. South*

In this appendix, I will discuss the workings of the amended model. First, I characterize the cross-national price disparities that arise in equilibrium. Second, I highlight how the cross-national variation in production and expenditure shares affect the structure of foreign trade. In what follows I will consider and equilibrium with uniform trade costs, and two categories (namely, H and L) such that $\sigma_H > \sigma_L$. Within this environment, I will compare the production, consumption, and trading behavior of two countries, namely the North, n, and the South, s, where $\alpha_n > \alpha_s$, and $L_n = L_s$. Given that n and s face the same vector of transport costs, it follows from the balanced trade condition that $w_n > w_s$.

Autarky Relative Prices. Based on Equation 3 in Section 2.2, The North has a revealed comparative advantage in the low-σ category, L. This notion of comparative advantage fits into the conventional definition that countries have a comparative advantage in a good for which they have a lower autarky relative price (Deardorff (1980)). To demonstrate this, note that (in the amended model) the relative *price index* of category H to L in country i is given by

$$\left(\frac{P_{i,H}}{P_{i,L}}\right)^{\text{Autarky}} = \phi \left[\frac{\alpha_i L_i}{\bar{\sigma}_i}\right]^{\frac{1}{\sigma_L - 1} - \frac{1}{\sigma_H - 1}}, \tag{8}$$

where $\frac{1}{\bar{\sigma}_i} \equiv \sum_{z=H,L} \frac{e_{i,z}}{\sigma_z}$ (with $e_{i,z}$ denoting the within-industry *autarky* expenditure share on category z), and $\phi \equiv \frac{\sigma_H(\sigma_L - 1)}{\sigma_L(\sigma_H - 1)}$. Given that $\alpha_n > \alpha_s$ and $\sigma_L < \sigma_H$, Equation 8 entails that the autarky relative *price index* of the high-σ category, H, is higher in the North than in the South:[14]

$$\left(\frac{P_{n,H}}{P_{n,L}}\right)^{\text{Autarky}} > \left(\frac{P_{s,H}}{P_{s,L}}\right)^{\text{Autarky}}. \tag{9}$$

Simply put, North's revealed comparative advantage in category L coincides with a lower autarky relative price index in that category.[15]

[14] Notice that $\frac{\partial e_{i,H}}{\partial \alpha_i} > 0$, which implies that $\frac{\partial}{\partial \alpha_i} \frac{L_i}{\bar{\sigma}_i} > 0$. More specifically, all else the same, an increase in α increases the expenditure share on category L, creating a greater scope for firm entry.

[15] Equation 9 also implies that larger economies have comparative advantage in the low-σ category, a pattern highlighted in Helpman and Krugman (1985).

Relative Prices and Expenditures with Trade Trade induces price indexes to converge across various markets. In particular, present trade, the relative price index of the the high-σ category drops in the North (n). However, unless trade costs are fully eliminated, price indexes are not equalized across markets, with the low-σ category remaining relatively cheaper in the North:

$$\left(\frac{P_{n,H}}{P_{n,L}}\right)^{\text{Autarky}} > \frac{P_{n,H}}{P_{n,L}} > \frac{P_{s,H}}{P_{s,L}} > \left(\frac{P_{s,H}}{P_{s,L}}\right)^{\text{Autarky}}.$$

Precisely speaking, the above result follows from the fact that price indexes under costly trade are a weighted CES average of all international prices, with more weight assigned to local prices.[16] Considering the above inequality, it follows immediately that the North (n) spends relatively more on the low-σ category, H. In particular,

$$\frac{E_{n,H}}{E_{n,L}} = \left(\frac{P_{n,H}}{P_{n,L}}\right)^{1-\eta} < \left(\frac{P_{s,H}}{P_{s,L}}\right)^{1-\eta} = \frac{E_{s,H}}{E_{s,L}}.$$

Trade frictions, therefore, induce countries with identical, homothetic preferences to display different expenditure behaviors. Furthermore, these differences are systematic whereby the consumption of a country mirrors its production abilities.[17]

Trade-to-GDP ratios. The patterns highlighted above have sharp implications about the structure of foreign trade. To demonstrate this, suppose that $\sigma_H \gg \sigma_L$. Considering the patterns of revealed comparative advantage, the North both produces and consumes relatively more of the low-σcategory, which is subject to *effective*ly lower trade costs: $\tau_{ji}^{\sigma_H - 1} \ll \tau_{ji}^{\sigma_L - 1}$ (note that category L also exhibits a greater profit margin, which make it more resilient to *fixed* exporting costs). Letting $\lambda_{ii,z} \equiv \frac{X_{ii,z}}{E_{i,z}}$ denote the domestic expenditure share in category z, country i's

[16]Obviously, under free trade ($\tau_{ji} = 1,\ \forall i, j$), we will have full international price parity:

$$\left(\frac{P_{n,H}}{P_{n,L}}\right)^{\text{Free Trade}} = \left(\frac{P_{s,H}}{P_{s,L}}\right)^{\text{Free Trade}}.$$

[17]These effects has a flavor similar to the "home-market effect" in Krugman (1980). The "home-market effect" implies that local demand determines patterns of local production, whereas here (in face of costly trade) local production determines the structure of local consumption.

trade-to-GDP ratio can be written as

$$\left(\frac{\text{Trade}}{\text{GDP}}\right)_i = (1-\lambda_{ii,L})\,\frac{E_{i,L}}{E_i} + (1-\lambda_{ii,H})\,\frac{E_{i,H}}{E_i}$$

In the South (when η is sufficiently large) consumption in each industry is dominated by the less-tradable, high-σ category (i.e., $\frac{E_{s,H}}{E_s} \approx 1$) that is sourced predominantly from local firms (i.e., $\lambda_{ss,H} \approx 1$). This implies a relatively small trade-to-GDP levels in the South:

$$\left(\frac{\text{Trade}}{\text{GDP}}\right)_s \approx 1-\lambda_{ss,H} \approx 0$$

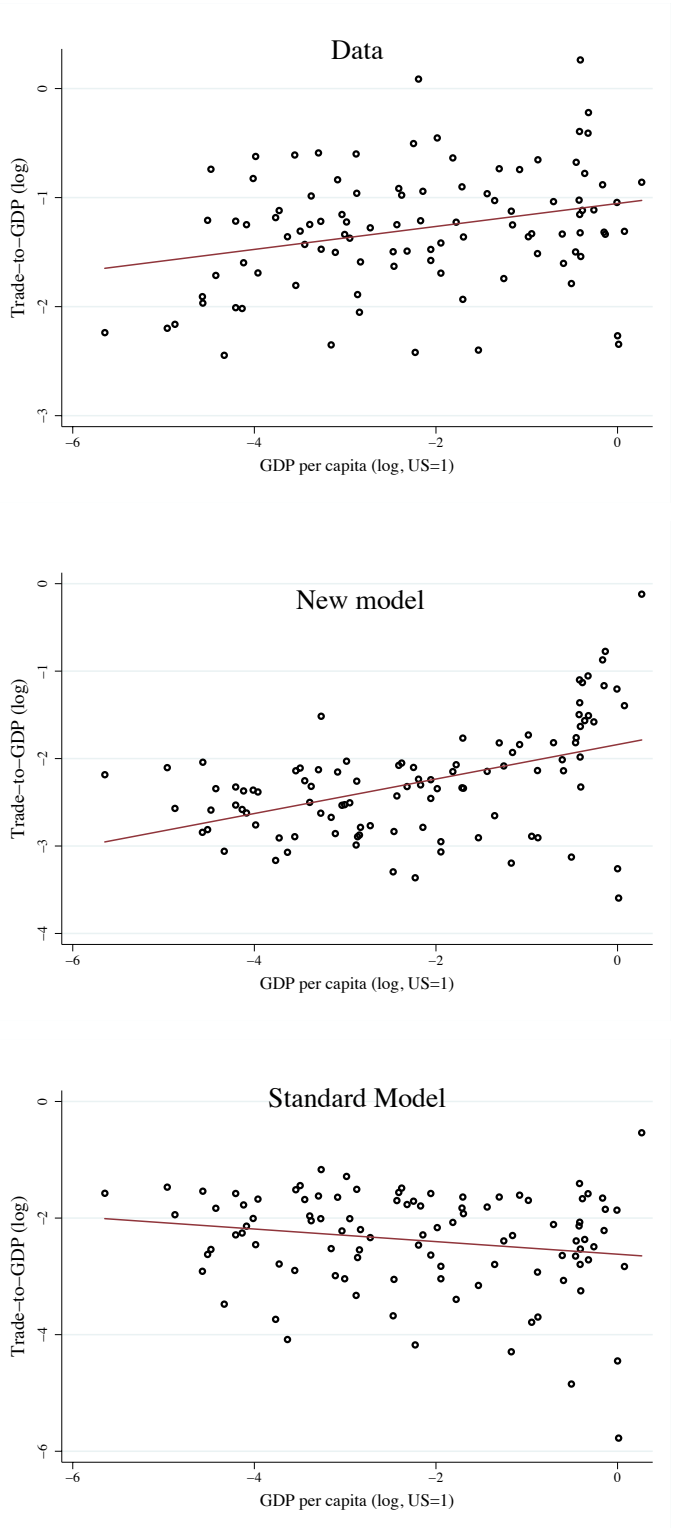
In the North, expenditure is concentrated on the highly-tradable, low-σ category (i.e., $\frac{E_{n,L}}{E_n} \approx 1$) which involves sizable two-way intra-category trade. The North, therefore, imports a larger fraction of its total expenditure:[18]

$$\left(\frac{\text{Trade}}{\text{GDP}}\right)_n \approx 1-\lambda_{nn,L} \approx 1-\frac{\alpha_n L_n}{\sum_{j=1}^{N}\alpha_j L_j}$$

Altogether, the amended model predicts that (i) trade-to-GDP levels are systematically lower in Southern (i.e., low-wage) countries, and (ii) North-North trade, which involves highly-tradable goods, is conducted more intensively than South-South trade, which involves less-tradable goods. In comparison, the standard two-sector gravity model delivers opposite predictions with respect to trade-to-GDP levels and the relative importance of South-South to North-North trade. Figure 7, which is produced with the estimated models, illustrates these distinctions.

[18]The above equation follows from the fact that $\frac{X_{jn,L}}{X_{nn,L}} \approx \frac{\alpha_j}{\alpha_n}\frac{M_j}{M_n}$ and $\frac{M_j}{M_n} \approx \frac{L_j}{L_n}$, when σ_H approaches unity.

Figure 7: *Trade-to-GDP × income per capita*



Note: the data corresponds to the year 2000, and is described in Section 3. The predicted values correspond to the amended and standard gravity models fitted to trade data from the same year.

C Cross-Elasticity Effects versus Non-homotheticity

In the amended model, cross-national differences in the expenditure structure are driven by cross-elasticity effects. That is, trade frictions lead to cross-category price disparities across markets, inducing relatively more expenditure on locally abundant categories in each country. Alternatively, the structure of cross-national expenditure shares may be regulated by non-homothetic preferences. In this paper, I purposely abstracted from non-homotheticity, since it cannot be separately identified from cross-elasticity effects in aggregate cross-sectional trade data. To illustrate this, suppose that preferences are non-homothetic and have a formulation similar to that assumed in Fieler (2011):

$$U_i = \left[\sum_{z \in \{H,L\}} \frac{\eta_z - 1}{\eta_z} U_{i,z}{}^{\frac{\eta_z - 1}{\eta_z}} \right]$$

Cross-category expenditure shares in country i are described by

$$\frac{E_{i,L}}{E_{i,H}} = \lambda^{\eta_H - \eta_L} \left(\frac{P_{i,L}^{1-\eta_L}}{P_{i,H}^{1-\eta_H}} \right) \tag{10}$$

where $\lambda > 0$ is the Lagrange multiplier associated with the utility maximization problem, and is strictly decreasing in the consumer's total income. Consider two countries, namely the North (n) and the South (s) where $w_n > w_s$. Data on trade values suggest that the North spends relatively more on their comparative advantage, low-σcategory, L: $E_{n,H} > E_{n,L}$. Additionally, the relative price index of the low-σ category is also lower in the North: $P_{n.H}/P_{n,L} > P_{s.H}/P_{s,L}$. Hence, the higher Northern expenditure on category L may be driven by either the a higher η_H (which governs the cross-elasticity effects) or a greater spread, $\frac{\eta_L}{\eta_H}$ (which corresponds to the degree of non-homotheticity; with good L being income-elastic: $\eta_L > \eta_H$).

Relying on only aggregate trade values, one cannot separately identify the cross-elasticity effects from non-homotheticity. Non-homothetic models typically handle the identification issue by normalizing η_H and estimates $\frac{\eta_L}{\eta_H}$.[19] The present paper

[19] Fieler (2011) sets $\epsilon_H = 5$. Similarly, Caron, Fally, and Markusen (2014) normalize $\epsilon_{\text{Texteile}} =$

instead normalizes $\frac{\eta_L}{\eta_H} = 1$ (which amounts to a homothetic demand structure) and estimates $\eta_H = \eta_L \sim \eta$, which delivers $\eta = 2.11$. At a broader level, the identification issue highlighted above resembles a general identification issue faced by the quantitative trade literature. In cross-sectional data, *taste* cannot be separately identified from *trade costs*; non-homotheticity is driven by taste, whereas cross-elasticity effects are driven by trade costs. Recently, several studies have employed richer data to disentangle these two forces (see Cosar, Grieco, Li, and Tintelnot (2015); Head and Mayer (2015)).

Table 4: *The Gains from Trade: Amended vs. Standard Model*

	Gains from Trade			
	Standard Model	Amended Model	Population Size (*million*)	GDP p/c (*US=1*)
Country	(1)	(2)	(3)	(4)
USA	0.5%	0.9%	280.00	1.00
JPN	0.4%	0.6%	130.00	1.01
DEU	2.1%	4.0%	82.00	0.66
GBR	2.0%	2.6%	60.00	0.67
FRA	2.3%	4.7%	59.00	0.63
CHN	1.1%	1.0%	1300.00	0.03
ITA	2.0%	3.4%	57.00	0.55
CAN	2.3%	7.1%	31.00	0.65
BRA	0.9%	0.8%	170.00	0.11
MEX	1.3%	3.9%	98.00	0.17
ESP	2.2%	3.6%	40.00	0.41
KOR	1.4%	1.1%	47.00	0.31
IND	2.0%	1.1%	1000.00	0.01
AUS	0.8%	1.0%	19.00	0.60
NLD	3.2%	6.2%	16.00	0.70
TWN	1.9%	1.4%	22.00	0.42
ARG	1.7%	1.3%	37.00	0.22

1, and control for the *normalized* price effects by constructing price indexes from the first-stage estimation.

Table 4: *The Gains from Trade: Amended vs. Standard Model*

	Gains from Trade			
	Standard Model	Amended Model	Population Size (*million*)	GDP p/c (*US=1*)
Country	(1)	(2)	(3)	(4)
RUS	2.9%	2.2%	150.00	0.05
CHE	4.9%	7.4%	7.20	0.99
SWE	3.4%	5.9%	8.90	0.77
BEL	5.2%	10.7%	10.00	0.66
TUR	3.4%	1.8%	67.00	0.09
AUT	4.7%	9.8%	8.00	0.68
SAU	3.4%	2.0%	21.00	0.26
POL	4.0%	2.8%	38.00	0.13
HKG	3.1%	3.4%	6.70	0.72
NOR	3.7%	5.4%	4.50	1.08
IDN	1.6%	1.2%	210.00	0.02
DNK	4.1%	8.8%	5.30	0.86
ZAF	2.0%	1.0%	44.00	0.08
THA	2.4%	1.5%	61.00	0.06
FIN	4.3%	7.6%	5.20	0.66
VEN	2.8%	1.5%	24.00	0.14
ISR	4.2%	3.4%	6.30	0.54
GRC	4.2%	4.3%	11.00	0.29
PRT	3.9%	5.2%	10.00	0.31
IRN	3.6%	1.8%	64.00	0.04
EGY	4.4%	2.3%	67.00	0.04
IRL	5.7%	10.6%	3.80	0.72
SGP	3.3%	3.7%	4.00	0.66
MYS	3.0%	2.9%	23.00	0.11
COL	3.3%	1.6%	42.00	0.06
PHL	3.4%	1.7%	76.00	0.03
CHL	2.7%	1.3%	15.00	0.14
PAK	4.5%	2.2%	140.00	0.01

Table 4: *The Gains from Trade: Amended vs. Standard Model*

	Gains from Trade			
	Standard Model	Amended Model	Population Size (*million*)	GDP p/c (*US=1*)
Country	(1)	(2)	(3)	(4)
ARE	4.5%	4.1%	3.20	0.63
CZE	6.3%	4.5%	10.00	0.16
DZA	6.3%	2.9%	30.00	0.05
PER	3.5%	1.6%	26.00	0.06
NZL	2.1%	1.6%	3.90	0.39
HUN	6.4%	3.6%	10.00	0.14
BGD	3.9%	1.8%	130.00	0.01
NGA	4.5%	2.0%	120.00	0.01
KWT	5.8%	4.5%	2.20	0.49
ROM	6.5%	3.0%	22.00	0.05
LBY	6.7%	3.4%	5.30	0.18
MAR	6.9%	3.1%	28.00	0.03
UKR	6.9%	3.5%	49.00	0.02
VNM	4.6%	2.4%	78.00	0.01
URY	5.2%	4.6%	3.30	0.18
SVK	9.3%	4.9%	5.40	0.11
LUX	15.5%	39.5%	0.44	1.30
OMN	6.8%	4.1%	2.40	0.24
DOM	6.3%	2.5%	8.70	0.07
TUN	10.0%	4.1%	9.60	0.06
SYR	8.2%	3.9%	17.00	0.03
SVN	9.7%	6.5%	2.00	0.27
HRV	9.5%	4.2%	4.50	0.11
KAZ	6.5%	3.1%	15.00	0.03
QAT	7.7%	9.1%	0.61	0.85
LBN	9.2%	4.2%	3.80	0.13
LKA	5.1%	2.1%	19.00	0.02
CRI	6.4%	2.4%	3.90	0.12

Table 4: *The Gains from Trade: Amended vs. Standard Model*

	Gains from Trade			
	Standard Model	Amended Model	Population Size (*million*)	GDP p/c (*US=1*)
Country	(1)	(2)	(3)	(4)
ECU	6.2%	2.4%	12.00	0.04
UZB	7.0%	3.0%	25.00	0.02
SLV	7.1%	2.5%	6.30	0.06
BLR	10.2%	4.7%	10.00	0.04
KEN	7.0%	3.3%	31.00	0.01
BGR	10.1%	4.6%	8.10	0.05
SDN	7.9%	4.3%	33.00	0.01
LTU	11.1%	5.0%	3.50	0.09
CIV	7.2%	3.0%	17.00	0.02
CMR	8.8%	3.4%	15.00	0.02
YEM	8.6%	3.8%	18.00	0.01
CYP	10.5%	6.4%	0.69	0.37
AGO	6.2%	2.5%	14.00	0.02
TZA	7.5%	2.8%	34.00	0.01
ISL	10.2%	12.6%	0.28	0.87
YUG	12.9%	5.1%	8.10	0.03
JOR	11.4%	5.2%	4.80	0.05
BOL	7.9%	3.4%	8.30	0.03
TTO	11.2%	4.1%	1.30	0.18
JAM	13.6%	3.9%	2.60	0.09
BHR	10.1%	5.7%	0.67	0.34
ETH	9.3%	4.0%	64.00	0.00
LVA	12.9%	5.3%	2.40	0.09
ZWE	7.6%	3.0%	13.00	0.02
PRY	8.8%	6.3%	5.30	0.04
BWA	8.0%	3.2%	1.80	0.10
UGA	9.8%	4.3%	24.00	0.01