Comparative Advantage, End Use, and the Gains from Trade

Amanda Kurzendoerfer*

University of Virginia

May 22, 2015

Abstract

This paper studies the importance of distinguishing between intermediate and final use for the gains from trade. I show analytically that failure to account for end-use heterogeneity in a one-sector, one-factor model systematically understates the gains from trade. To fully quantify the discrepancy, I construct and solve a multi-sector, multi-factor model with input-output linkages that incorporates end-use variation. End-use variation increases the gains from trade by 14.4 percent on average. The parameter estimates reveal that lower income countries have a comparative disadvantage in producing intermediates and pay relatively more to import them, which results in a higher price of intermediate relative to final goods in these countries.

*This research was supported by the Bankard Fund for Political Economy and the Albert Gallatin Graduate Research Fellowship at the University of Virginia. I am grateful for helpful comments from James Harrigan, John McLaren, Ariell Reshef, and Peter Debaere.

1 Introduction

In the Ricardian model of international trade, countries benefit from trade by specializing in the activities in which they are relatively more productive. A trade liberalization allows countries to produce and export more of their comparative advantage sectors and import more of their comparative disadvantage sectors. The larger the productivity differences, the larger the reallocations, and the larger the gains from trade. Productivity differences are therefore central to determining the gains from trade. International trade data suggests that productivity varies by intermediate and final end use; that is, some countries are relatively better at producing goods intended for intermediate use and others are relatively better at producing goods intended for final consumption. Despite apparent productivity differences, comparative advantage by end use has not been explored as an avenue for the gains from trade. In this paper, I construct a general equilibrium Ricardian trade model that features productivity differences by intermediate and final use to determine their contribution to the gains from trade.

Distinguishing productivity by end use highlights the different roles of intermediate and final goods in an economy, and their different contributions to the gains from trade. Intermediates are used in the production of intermediates, which are used in the production of other intermediates and so on (and ultimately final goods), so the gains from trade are magnified when intermediate productivity improves or barriers to trading intermediates are reduced. In contrast, final goods are consumed once, so the benefit of a productivity improvement or trade liberalization in final goods passes directly to the consumer, but does not accumulate through the production process. The existing literature does not incorporate productivity differences that arise by virtue of a good's end-use classification, potentially masking an asymmetric response of the gains from trade to adjustments in the characteristics of intermediate and final use trade.

The evidence that productivity varies by end use comes from a single statistic, the domestic expenditure share. In a Ricardian framework with costly trade, a country's share of total expenditure on domestically produced goods, or its domestic expenditure share, contains information about its comparative advantage and access to imports. A high share implies that a country is either very productive at producing a particular good or that it faces significant barriers to importing the good from low cost locations. Figure **??** plots the domestic expenditure share for intermediates against the domestic expenditure share for final goods for 40 countries.[1] If productivity and trade barriers did not vary by end use, the shares would not vary by end use, and the points in Figure **??** would lie on the 45°-line. As the figure shows, intermediate and final domestic expenditure shares are correlated—countries that purchase a large share of intermediates from home tend also to purchase a large share of final goods from home—but the difference is often large and varies by country. The difference between shares ranges from as much as 32 percent (Luxembourg), to as little as minus three percent (Russia, the only country for which the intermediate domestic share is higher). Within-country differences in intermediate and final domestic expenditure shares indicate that productivity, trade costs, or both vary by end use.

Because the domestic expenditure share captures information about a country's comparative advantage and access to imports, it is central to determining the country's gains from trade. Arkolakis, Costinot, and Rodríguez-Clare (2012) show that the domestic expenditure share and the trade cost elasticity are the only variables needed to compute the gains from trade relative to autarky across a wide class of models. I show that the expression for the gains from trade in a simple one-sector, one-factor version of the full model with end-use variation is a function of *both* the intermediate and final domestic expenditure shares, and the trade cost elasticity. This is in contrast to the same model without end-use variation (Eaton

[1] All calculations are based on data from the World Input-Output Database (WIOD), http://www.wiod.org/new_site/home.htm, which I describe in Section **??**.

and Kortum, 2002), in which the *overall* domestic expenditure share and the trade cost elasticity determine the gains from trade. I show that the model without end-use variation will always understate the gains from trade when trade is balanced (and the intermediate and final domestic expenditure shares are not the same). Further, I demonstrate the asymmetry of the elasticity of the gains from trade with respect to intermediate and final domestic expenditure shares.

Differences in intermediate and final domestic expenditure shares generate gains from trade, and the shares contribute asymmetrically to the gains from trade. Determining the underlying productivity differences that generate differences in the shares is therefore a potentially informative exercise. The simple model provides an expression that relates intermediate relative to final domestic expenditure shares to relative technology and relative prices. Relative prices reflect a country's ability to access intermediates vis à vis final goods at low cost. In a first look at comparative advantage by use, I use data on the relative price of intermediates—which is sharply decreasing in income—to extract relative productivities from the domestic expenditure shares. I find that low income countries have a comparative disadvantage in the production of intermediates.

The simple model provides an analytical expression for the gains from trade and the relationship between domestic expenditure shares and comparative advantage, but it does not incorporate the full extent of productivity differences by end use. The data also show that domestic expenditure shares vary by end use within industries. Figure **??** plots the intermediate share against the final share for 32 goods and service industries in 38 countries.[2] The point *Japan, Leather Goods*, for example, demonstrates that Japan turns to domestic producers for 92 percent of its intermediate leather requirements, but is considerably more open in its purchases of leather final goods—the domestic expenditure share is just 20 per-

[2] I combine the three small, open economies Cyprus, Luxembourg, and Malta, and some industries to avoid observations of zero gross output, as I describe in Section **??** (See Tables **??** and **??** for the country and industry aggregation schemes.)

cent. To capture this variation, and to incorporate the fact that an industry's output is used in varying intensities by other industries, I construct a multi-industry Eaton and Kortum (2002) model with input-output linkages and end-use variation within industries. The model features Ricardian motives for trade at the industry-by-end-use level, and also incorporates multiple factors (labor and capital). The full model does not provide an analytical expression for the gains from trade, so I estimate the parameters using three different regression techniques and solve the model numerically to determine the contribution of end-use variation to the gains from trade; I find that the gains from trade are 14.4 percent higher on average under a model with end-use variation than under a model without. This increase is more than one-third the size of the increase in the gains from trade contributed by multiple factors of production, sectoral heterogeneity, and input-output linkages.

I also use the parameter estimates from the full model to provide a closer look at comparative advantage. The estimates support the aggregate result that lower income countries have a comparative disadvantage in producing intermediates relative to final goods. I find that this result is driven by a comparative disadvantage in intermediate agriculture and manufacturing industries (and to some extent service industries) in these countries. Further, low income countries pay relatively more to import intermediates. A comparative disadvantage in intermediate production and a high cost to import are consistent with low income countries paying a higher relative price for intermediates, which the aggregate data show and my parameter estimates support. I also show that intermediates are more tradable than final goods, and that the estimates imply a Balassa-Samuelson effect: countries that have a comparative advantage in the production of more tradable goods (intermediates) pay a relatively higher price for less-tradable goods (final goods).

Recent literature has sought to quantify the gains from trade under the different sources of heterogeneity that Arkolakis et al. present in their theoretical paper. Examples include Costinot and Rodríguez-Clare (2013), Levchenko and Zhang (2014), and Caliendo and Parro

(2012). Costinot and Rodríguez-Clare find that multiple sectors and tradable intermediate goods have larger effects on the gains from trade than market structure and firm-level heterogeneity. Levchenko and Zhang find that sectoral heterogeneity increases the gains from trade by 30 percent relative to a one-sector model, and show analytically that the one-sector model will always understate the gains from trade. Caliendo and Parro estimate the welfare effects of NAFTA, and find that welfare is reduced by more than 40 percent when intermediate goods and country-varying input-output linkages are not considered. This paper is the first to quantify the contribution of end-use variation to the gains from trade. I do this using a model that includes end-use variation, as well as the sectoral heterogeneity, tradable intermediate inputs, and input-output linkages that the literature described above has shown are important channels for the gains from trade. This paper and those above rely on the multi-sector Eaton and Kortum framework that was introduced by Shikher (2011, 2012, and 2013) and Chor (2010). The model is also related to Melitz and Redding (2014), who show that the gains from trade in a model with sequential production become arbitrarily large as the number of production stages increases. Distinguishing end-use, I construct a model with two stages of production: intermediates (stage one) are required to produce final goods (stage two).[3] The empirics in this paper are related to Levchenko and Zhang (2013), who use a multi-sector Eaton and Kortum model to estimate technology parameters and find that comparative advantage has weakened over time. I also use the parameter estimates to assess comparative advantage, but by end use and across countries rather than by industry and over time.

Literature that features end-use variation centrally is outside the context of the literature on the gains from trade, and typically focuses on the importance of low trade barriers and productivity in intermediates vis à vis final goods. Amiti and Konings (2007) find that,

[3]The structure of intermediate production itself is "roundabout" rather than sequential, in that any intermediate input can be used in the production of another intermediate.

in the context of an Indonesian trade liberalization, a decline in tariffs on intermediate inputs leads to a productivity gain for firms that import their inputs that is at least twice as high as the gain from reducing tariffs on final goods. Jones (2011) shows that linkages through intermediate goods generate a productivity multiplier that helps to explain large income differences across countries. A United Nations Conference on Trade and Development (2013) report discusses the importance of participation in global value chains—which is determined by the proportion of a country's exports that are part of a multi-stage production process, and is therefore an indication of participation in intermediate goods trade—for generating employment and increasing GDP and income growth. These papers demonstrate that there are important benefits to improved competitiveness in intermediates. I explore this idea further—first by showing analytically that the gains from trade are more responsive to changes in intermediate trade, and second by showing that technology, trade costs, and prices vary by end use in a way that is related to income.

The rest of this paper is organized as follows. In Section **??** I set up a one-sector, one-factor model with end-use variation. I show that a model that fails to account for this variation will weakly understate the gains from trade, and that the size of the discrepancy depends on the ratio of final to intermediate domestic expenditure shares and the labor share. I show the circumstances under which the gains from trade are more responsive to changes in the intermediate domestic expenditure than to changes in the final domestic expenditure share, and use aggregate data to demonstrate the magnitude of the discrepancy in the gains from trade and to quantify the elasticities. In Section **??** I take a first look at comparative advantage, showing the implications for relative technology levels given data on intermediate and final prices and domestic expenditure shares. In Section **??** I set up the full general equilibrium model, incorporating variation in end use at the industry level, input-output linkages, and capital. In Section **??** I describe the estimation procedure and the data. Section **??** describes the data and implementation for estimation. Section **??** presents the results of the estimation, shows that the relative parameter estimates are related to income, and demonstrates evidence of the Balassa-Samuelson effect. In Section **??** I use the estimated parameters to solve the full general equilibrium model to show the effect of incorporating end-use heterogeneity on the gains from trade. Section **??** concludes.

2 Simple model and some magnitude

I first describe an extension of the Eaton and Kortum (2002) model that incorporates variation in end use. I demonstrate that the standard model understates the gains from trade, and that the discrepancy depends on two variables: the ratio of the intermediate and final domestic expenditure shares and the labor share. I also show that the gains from trade are more responsive to changes in the intermediate domestic expenditure share when the intermediate share in total output is greater than 50 percent, and more responsive than the standard model implies when the intermediate domestic expenditure share is less than the final domestic expenditure share. I then turn to the data to demonstrate the magnitude of the discrepancy and the elasticities of the gains from trade with respect to intermediate and final domestic expenditure shares for the 38 countries in my sample.

2.1 Simple model with end-use variation

There are N countries. Production is Cobb-Douglas over labor and intermediates, with unit costs in country i given by $c_i = w_i^{\beta_i}(p_i^I)^{1-\beta_i}$, where w_i is the wage, p_i^I is the price of a bundle of intermediates, and β_i is the labor share in total output $(0 < \beta_i < 1)$.[4] Countries produce varieties of intermediate and final goods, and varieties are produced with productivities that vary by end use. End use is distinguished by $u = \{I, F\}$, varieties

[4]In a minor departure from Eaton and Kortum, I allow the labor share to vary by country. This has implications for the full general equilibrium solution, but, other than allowing the elasticity of the gains from trade with respect to the overall domestic expenditure share to vary by country, it does not change the standard gains from trade formula.

are indexed by l on $[0,1]$, and productivity is given by $z_i^u(l)$. Productivity is drawn from a Fréchet distribution with location parameter T_i^u and dispersion parameter θ. T_i^u is the absolute productivity level for country i, end use u, and the ratio of intermediate to final technology levels determines comparative advantage in producing goods suited for each end use. That is, $T_i^I/T_i^F > T_{i'}^I/T_{i'}^F$ means that country i has a comparative advantage in the production of intermediate relative to final goods compared to country i'. Trade costs vary by end use and take the iceberg form: τ_{ni}^u units of the good destined for end use u in country n must be shipped from i for one unit to arrive (within-country trade costs are normalized to one, $\tau_{ii}^u = 1$). Perfect competition implies that a buyer in country n would pay $p_{ni}^u(l) = c_i\tau_{ni}^u/z_i^u(l)$, the productivity-adjusted unit cost times the iceberg trade cost, if the variety were bought from country i. Buyers, who can be producers shopping for intermediates or consumers shopping for final goods, purchase the variety from the lowest-cost source and combine varieties in CES fashion. The technology distribution and CES price index yield a closed form expression for prices paid for intermediate and final goods in the destination country: $p_n^u = \gamma\left[\sum_{i=1}^N T_i^u(c_i\tau_{ni}^u)^{-\theta}\right]^{-1/\theta}$. The probability that country i is the lowest cost provider of variety l to country n, which is also the fraction of expenditure by country n on goods from country i is $\pi_{ni}^u = \frac{X_{ni}^u}{X_n^u} = T_i^u\left(\frac{\gamma c_i\tau_{ni}^u}{p_n^u}\right)^{-\theta}$, where X_{ni}^u is expenditure by country n on goods of end use u from country i and X_n^u is expenditure by country n on goods of end use u from all countries. The fraction of expenditure by country i on goods from itself, the domestic expenditure share, is $\pi_{ii}^u = T_i^u\left(\frac{\gamma c_i}{p_i^u}\right)^{-\theta}$.

To solve for the gains from trade, I first find real wages by substituting the unit cost function into the final domestic expenditure share equation ($u = F$) and rearranging:

$$\frac{w_i}{p_i^F} = \gamma^{-1/\beta_i}\left(\frac{T_i^F}{\pi_{ii}^F}\right)^{1/\beta_i\theta}\left(\frac{p_i^F}{p_i^I}\right)^{1/\beta_i-1}. \tag{1}$$

Welfare is measured by the purchasing power of wages in terms of the final good, the price of which may differ from the price of the intermediate good. The price of the intermediate good affects real wages indirectly through the use of intermediates in production of the final good (and through general equilibrium effects on the wage). I next use the domestic expenditure share equation for both final and intermediate goods to write relative prices as a function of relative domestic expenditure shares and technology levels:

$$\frac{p_i^F}{p_i^I} = \left[\left(\frac{\pi_{ii}^I}{\pi_{ii}^F}\right)\left(\frac{T_i^F}{T_i^I}\right)\right]^{-1/\theta}, \tag{2}$$

and substitute (**??**) into (**??**):

$$\frac{w_i}{p_i^F} = \gamma^{-1/\beta_i}\left[\left(\frac{T_i^F}{\pi_{ii}^F}\right)^{\beta_i}\left(\frac{T_i^I}{\pi_{ii}^I}\right)^{1-\beta_i}\right]^{1/\beta_i\theta}. \tag{3}$$

The change in real wages, $\widehat{W} \equiv \left(w_i/p_i^F\right)'/\left(w_i/p_i^F\right)$, associated with a move from autarky ($\pi_{ii}^u = 1$) to trade is then:

$$\widehat{W} = \left[\left(\pi_{ii}^F\right)^{\beta_i}\left(\pi_{ii}^I\right)^{1-\beta_i}\right]^{-1/\beta_i\theta}. \tag{4}$$

This expression has the counterpart $\pi_{ii}^{-1/\beta_i\theta}$ in the standard model. The expressions differ in terms of the interior component: the model with end-use variation relies on a geometric weighted average of the intermediate and final domestic expenditure shares, while the standard formulation depends on the overall domestic expenditure share (π_{ii}). Before formalizing the conditions under which the two gains from trade expressions diverge, I discuss the intuition behind the expression that incorporates end-use variation.

Rearranging the exponents, we can rewrite (**??**) as $\widehat{W} = \left(\pi_{ii}^F\right)^{-1/\theta}\left(\pi_{ii}^I\right)^{-(1-\beta_i)/\beta_i\theta}$. The elasticity of the gains from trade with respect to the final domestic expenditure share is $-1/\theta$, as it is in the gains from trade expression with no intermediates (see Arkolakis et al. equation (1)), where θ is the trade cost elasticity. Final goods are not used in the production of other goods, so openness in final goods is not subject to the amplification in the gains from trade that arises when a good is part of an input-output loop. In contrast, intermediates are used in the production of other intermediates, so the gains from trade are amplified by the share of intermediates in total expenditure (precisely by the labor share, which is one minus the intermediate share), hence the presence of β_i in the denominator of the exponent on the intermediate domestic expenditure share (see Arkolakis et al. Section IV.B). Because welfare is measured by the purchasing power of wages in terms of final goods, this magnification effect is only directly relevant to the gains from trade through the extent to which final goods rely on intermediates, hence the presence of $1-\beta_i$ in the numerator of the exponent. Thus, we can think of the gains from trade as being determined directly by openness in final goods, and indirectly by openness in intermediates through two channels: the effect on other intermediates, and on final goods.

I now show that the gains from trade in a model without end-use variation will systematically understate the true gains from trade, and that the size of the discrepancy depends on the ratio of intermediate to final domestic expenditure shares and the labor share. First, rewrite the overall domestic trade share π_{ii} as a linear combination of the final and intermediate domestic expenditure shares, where β_i and $1-\beta_i$ are the weights when trade is balanced: $\pi_{ii} = \beta_i \pi_{ii}^F + (1-\beta_i)\pi_{ii}^I$.[5] Now we can easily compare the gains from trade formula with end use variation to the standard formulation: in the former the interior component is a geometric weighted average of the final and intermediate domestic trade shares, and in the latter it is a linear weighted average of the final and intermediate domestic trade shares. That is,

$$\widehat{W}_{End\text{-}Use} = \left[\left(\pi_{ii}^F\right)^{\beta_i} \left(\pi_{ii}^I\right)^{1-\beta_i} \right]^{-1/\beta_i\theta}, \tag{5}$$

[5]To see that the labor and intermediate shares in total output are the correct weights when trade is balanced, first recall notation—that X_i^u is expenditure by country i on goods of end use u. In equilibrium, payments to labor (the only factor of production) equal total expenditure on final goods X_i^F, and total output equals total expenditure, X_i. Thus, β_i is also the share of expenditure on final goods in total expenditure, X_i^F/X_i, and $1-\beta_i$ is the share of expenditure on intermediate goods in total expenditure, X_i^I/X_i. We can write the overall domestic expenditure share as $\pi_{ii} = (X_{ii}^F + X_{ii}^I)/X_i$, which is the same as $(X_i^F/X_i)(X_{ii}^F/X_i^F) + (X_i^I/X_i)(X_{ii}^I/X_i^I)$. It follows then that $\pi_{ii} = \beta_i \pi_{ii}^F + (1-\beta_i)\pi_{ii}^I$.

$$\widehat{W}_{Standard} = \left[\beta_i \pi_{ii}^F + (1-\beta_i)\pi_{ii}^I\right]^{-1/\beta_i\theta}. \tag{6}$$

Taking the logarithm of each interior component we see that, by Jensen's Inequality, the geometric expression will always be less than or equal to the linear expression:

$$\beta_i \ln \pi_{ii}^F + (1-\beta_i)\ln \pi_{ii}^I \leq \ln(\beta_i \pi_{ii}^F + (1-\beta_i)\pi_{ii}^I), \tag{7}$$

and strictly less when $\pi_{ii}^F \neq \pi_{ii}^I$. Because the gains from trade formulas are decreasing in their interior components, the standard formulation will always understate the end-use formulation when the intermediate and final domestic expenditure shares are not the same. This is Proposition 1.

Proposition 1 *When trade is balanced, the gains from trade in the standard one-sector model weakly understate the gains from trade in the one-sector model with end-use variation. That is:*

$$\widehat{W}_{Standard} = \left[\beta_i \pi_{ii}^F + (1-\beta_i)\pi_{ii}^I\right]^{-1/\beta_i\theta} \leq \left[\left(\pi_{ii}^F\right)^{\beta_i}\left(\pi_{ii}^I\right)^{1-\beta_i}\right]^{-1/\beta_i\theta} = \widehat{W}_{End\text{-}Use}.$$

The inequality is strict when $\pi_{ii}^F \neq \pi_{ii}^I$.

A corollary to the proposition is related to the size of the discrepancy, which we can determine analytically by taking the ratio of the end-use (**??**) and standard (**??**) versions and rearranging.

Corollary 1 *For a given θ, the discrepancy in the gains from trade between the end-use and standard models depends on the ratio of domestic trade shares (π_{ii}^F/π_{ii}^I) and the labor share (β_i):*

$$\widehat{W}_{End-Use}/\widehat{W}_{Standard} = \left(\frac{\pi_{ii}^F}{\pi_{ii}^I}\right)^{-1/\theta}\left[\beta_i\left(\frac{\pi_{ii}^F}{\pi_{ii}^I}\right) + (1-\beta_i)\right]^{1/\beta_i\theta}. \tag{8}$$

The further apart are the final and intermediate domestic trade shares and the lower β_i, the larger the discrepancy. The size of the overall trade share π_{ii} does not matter; it is the extent to which the domestic trade shares are different that affects the discrepancy in the gains from trade. Figure **??** plots the discrepancy in the gross gains from trade against a potential range of the ratio of final to intermediate domestic expenditure shares and the range of possible labor shares for $\theta = 4$.[6] As the figure shows, the discrepancy is largest when π_{ii}^F and π_{ii}^I are most different and β_i is low.

Turning now to the elasticity of the gains from trade with respect to each domestic expenditure share, equation (**??**) shows that the elasticities with respect to the final and intermediate domestic expenditure shares are $-1/\theta$ and $-(1-\beta_i)/\beta_i\theta$, respectively. Thus the elasticity with respect to the intermediate share will be larger than the elasticity with respect to the final share when $\beta_i < 0.5$, and it will be larger by a factor of $(1-\beta_i)/\beta_i$. The lower the labor share, the more responsive are the gains from trade to the intermediate domestic expenditure share than to the final share. As discussed previously, this is because intermediates are used more intensively in the production of other intermediates and in the production of final goods when the labor share is low. We can also compute the elasticity of the gains from trade with respect to each domestic trade share for the standard formulation. From equation (**??**), we can show that the elasticity with respect to the final domestic expenditure share is $(-1/\theta)(\pi_{ii}^F/\pi_{ii})$, and with respect to the intermediate domestic expenditure share is $(-(1-\beta_i)/\beta_i\theta)(\pi_{ii}^I/\pi_{ii})$. Thus the gains from trade are $((1-\beta_i)/\beta_i)(\pi_{ii}^I/\pi_{ii}^F)$ times more responsive to changes in the intermediate domestic expenditure share than to changes in the final domestic expenditure share, and the standard model will understate the importance of changes in the intermediate domestic expenditure share when $\pi_{ii}^I < \pi_{ii}^F$.

[6] I use $\theta = 4$ here and throughout the paper following Simonovska and Waugh (2014), who show that the Eaton and Kortum (2002) estimator is biased and will overestimate the elasticity of trade in finite sample sizes. Simonovska and Waugh develop a new estimator that reduces the bias and yields an estimate of θ that is roughly equal to 4.

The analytical expressions for the discrepancies between the end-use and standard models discussed above rely on the assumption of balanced trade—that the overall domestic expenditure share can be written as a linear combination of the intermediate and final domestic expenditure shares with respective weights β_i and $1 - \beta_i$. Trade is not balanced in practice, however, and a researcher following the standard procedure observes only the overall domestic expenditure share. It is therefore important to quantify the size of the actual discrepancy, or the discrepancy that would result from using the observed overall domestic expenditure share (not the labor share weighted average) to compute the gains from trade.

2.2 Size of the discrepancy

Table **??** reports the average overall, final, and intermediate domestic expenditure shares, the average ratio of final to average intermediate shares, and the average labor share for countries in three income classifications for the year 2007.[7] Income classifications are determined by the World Bank (see Table **??**); high income countries are the developed economies in North America, Europe, and the Asia-Pacific region, upper middle income economies include the transition economies in Central and Eastern Europe, as well as Brazil and Mexico, and the lower middle income countries are China, India, and Indonesia. Higher income countries are more open overall, and for the intermediate and final classifications individually. All groups purchase a larger share of final goods and services from home than intermediate goods and services ($\pi^F_{ii}/\pi^I_{ii} > 1$), and this fact tends to be more pronounced for the richer countries: the average ratio of final to intermediate domestic expenditure shares is 1.17 for the high income group and 1.06 for the lower middle income group. Labor shares are on average lower in lower income countries owing to relatively less service-sector output in these countries (34 percent for high income and 27 percent for lower middle income). Recalling equation (**??**)

[7]The simple model does not include capital as a factor of production, so I net capital compensation out of the labor share calculation. That is, *labor share* = *labor compensation*/(*gross output* − *capital compensation*).

and Figure ??, the discrepancy in the gains from trade across the two models is increasing in the domestic expenditure share ratio (when it is greater than one) and decreasing in the labor share, so it is not obvious a priori which group will experience the largest discrepancy.

Table ?? maps the domestic expenditure shares and labor shares into the gains from trade under the standard and end-use models, reports the discrepancy between the two, and also shows the relative elasticity of the gains from trade with respect to the intermediate and final domestic expenditure shares. As the table shows, the average discrepancy in the gains from trade across the two models is largest for the lower income countries (15.1 percent for upper middle and 16.2 percent for lower middle compared to 11.1 percent for high income). In this instance, the lower average labor shares (which increase the size of the discrepancy) in the upper middle and lower middle income classifications offset the effect of their lower average domestic expenditure share ratios (which reduce the size of the discrepancy) relative to the high income classification. The last column in Table ?? reports the relative elasticity of the gains from trade with respect to the intermediate and final domestic expenditure shares, which is $(1-\beta_i)/\beta_i$. The gains from trade are three times as responsive to the intermediate domestic expenditure share as to the final domestic expenditure share in the lower middle income group. This distinction between the responsiveness between intermediate and final domestic expenditure share is altogether missed in the standard model, and the relative elasticities are equal to one.

Underlying the averages is a considerable amount of variation across countries. Table ?? shows the country-level domestic expenditures shares, ratios, and labor shares, and Table ?? shows the gains from trade discrepancies and the relative elasticities. The size of the discrepancy ranges from -5 percent for Russia to 44 percent for Mexico.[8] The relative elasticity is as low as 1.3 in Greece, and the gains from trade are nearly five times as responsive

[8]The analytical discrepancy is always weakly positive when trade is balanced. The gains from trade under the standard model are calculated using the overall domestic expenditure share and trade is not necessarily balanced, so it is possible that the discrepancy is negative—as is the case for Russia.

to the intermediate domestic expenditure share as to the final domestic expenditure share in China. This is directly a consequence of China's low labor share and demonstrates the disproportionate importance of intermediates given their large share in China's production.

3 Comparative advantage, a first look

Domestic expenditure shares vary by end use and have different effects on the gains from trade, so as a next step I look at the factors that contribute to differences in relative domestic expenditure shares: prices and productivity. In this section I combine country-level data on prices of intermediate and final goods with the intermediate and final domestic expenditure shares to make an inference about the nature of comparative advantage across countries and end use. I continue to use the simple model in this section, showing in Section **??** the implications for comparative advantage using the full model.

A country that sources a relatively larger share of intermediates than final goods domestically will have a higher relative technology in producing intermediates or a higher relative price of intermediates. We can see this by rearranging equation (**??**):

$$\frac{\pi_{ii}^I}{\pi_{ii}^F} = \left(\frac{T_i^I}{T_i^F}\right)\left(\frac{p_i^I}{p_i^F}\right)^{\theta}. \tag{9}$$

If trade were completely costless and consequently the law of one price held, the relative price would be the same across countries, and differences in the relative domestic expenditure share would be governed only by relative technology levels. We would then conclude that comparative advantage in the production of intermediates is decreasing in income, as $(\pi_{ii}^I/\pi_{ii}^F)_{LowerMiddle} > (\pi_{ii}^I/\pi_{ii}^F)_{UpperMiddle} > (\pi_{ii}^I/\pi_{ii}^F)_{High}$, see Table **??**. Trade is far from costless, however, so we cannot make a statement about the relationship between comparative advantage and domestic expenditure shares without some knowledge of relative prices.

Prices are in principle observable, so together with relative domestic expenditure shares and an estimate of θ we can extract relative technology levels using the expression above.

I obtain the price of intermediates from the GGDC Productivity Level Database for the benchmark year 1997 and the price of final goods from the OECD, also for the year 1997. The intermediate prices are constructed from sectoral intermediate input PPPs, which reflect each sector's cost of acquiring intermediate deliveries.[9] The final prices are the PPPs for GDP, which cover both final consumption expenditure (household and government) and gross capital formation.[10] I take the ratio of the intermediate to the final price and normalize it to one in the US. The price data are available for 26 countries, and unfortunately exclude the lowest income countries in my initial data set. Nonetheless, there is a strong inverse relationship between the price of intermediates relative to final goods and per capita income.

Figure **??**, Panel (a) plots the relationship between relative domestic expenditure shares and income, and Panel (b) plots the relationship between relative prices and income.[11] Given that the ratio of domestic expenditure shares is flat to decreasing with respect to income (the inverse relationship is weaker here where the lowest income countries are excluded), and the price ratio is sharply decreasing (and also raised to a power $\theta > 1$), we can infer from equation (**??**) that the relative technology to produce intermediate goods will be increasing in income. Panel (c) of Figure **??** plots the precise relationship between relative technology and income, calculated under the assumption that $\theta = 4$. This calculation shows not only that lower income countries tend to have a comparative disadvantage in producing intermediates, but also that there is considerable variation in comparative advantage across countries—the

[9]The price of intermediate inputs in a country is computed as the geometric average of the PPP for sectoral intermediate inputs (*PPP_II*), with the share of sectoral intermediate expenditure (*II*) in total intermediate expenditure as the weights. The data are available at http://www.rug.nl/research/ggdc/data/ggdc-productivity-level-database. See Inklaar and Timmer (2008) and Timmer, Ypma, and van Ark (2007) for a detailed discussion of the construction of the PPPs.

[10]The PPPs for GDP are available at http://stats.oecd.org/#.

[11]Per capita income is given by output-side real GDP at chained PPPs in 2005 US dollars (*rgdpo*) per person (*pop*) for the year 1997 from the Penn World Tables Version 8.0, available at http://www.rug.nl/research/ggdc/data/pwt/pwt-8.0.

relative technology level for the country with the largest comparative advantage in producing intermediates, Denmark, is eight times that of the country with the largest comparative disadvantage in producing intermediates, the Czech Republic. The large amount of variation suggests that productivity differences at the end-use level provide an important channel for the gains from trade. The calculation is only suggestive, however, as it relies on the assumptions of a very basic model, uses highly aggregate data, and price data that may be measured with error. In the next section, I describe the full model, which incorporates many industries, labor and capital, and input-output linkages, and generates prices that vary by industry and end use. I use the full model to further assess the relationship between comparative advantage and income, and to evaluate the relationship between relative trade costs and relative prices and income. In Section **??**, I use the full model to quantify the contribution of end-use variation to the gains from trade.

4 Full model

In this section I construct the full model, which incorporates many sectors, input-output linkages, capital as a factor of production, and end-use variation. I allow the technology and trade cost parameters to vary by industry and end use, which generates prices and trade shares that also vary by industry and end use. I do this to capture the variation in domestic expenditure shares at this level (Figure **??**), and to incorporate end use variation as a channel for the gains from trade. The model is most closely related to the model described in Caliendo and Parro (2012). In the Caliendo and Parro model (and other multi-sector Eaton and Kortum models), an industry's output can be used both as an intermediate and as a final good, and the productivity and trade cost estimates are a composite of the productivity levels and trade costs associated with each type of end use. Assessing comparative advantage by end use and determining its effect on the gains from trade, however, requires a clear delineation between intermediate and final goods. I ensure that the sectoral productivity and trade cost measures do not confound differences across end use by completely separating intermediate and final goods within a sector; that is, an intermediate good is never used as a final good, and a final good is never used as an intermediate.[12] This characterization is consistent with the data, which classifies all sectoral trade flows and domestic production as destined for either intermediate or final use.

4.1 Production

Countries are denoted n and i, and industries are denoted k. End use is given by $u = [I, F]$. The cost of production in country i, industry k is a Cobb-Douglas function of labor, capital, and intermediate inputs:

$$c_i^k = \left(w_i^{\alpha_i^k} r_i^{\iota_i^k} \right)^{\beta_i^k} \left(\rho_i^k \right)^{1-\beta_i^k}, \tag{10}$$

where w_i is the wage, r_i is the rental rate, and ρ_i^k is the price of a bundle of intermediates. Labor and capital are mobile across industries within a country, and their shares in value added are α_i^k and ι_i^k. The share of value added in gross output is β_i^k and the share of intermediates in gross output is $1 - \beta_i^k$. The price of the bundle of intermediates used to produce an industry k good in country i is a Cobb-Douglas function of the prices of intermediate inputs from each industry k':

$$\rho_i^k = \prod_{k'} \left(p_i^{I,k'} \right)^{\eta_i^{k,k'}}, \tag{11}$$

where $\eta_i^{k,k'}$ is industry k's share of total expenditure spent on intermediates from industry k'. The input shares vary by country, and $\sum_{k'} \eta_i^{k,k'} = 1$. The literature commonly assumes

[12] The Caliendo and Parro model is flexible enough to handle this adjustment (by setting consumption shares to zero for intermediates and input shares to zero for final goods). Solving the model, however, requires knowledge of trade and domestic production by end use, which is not available in the widely used trade data.

constant industry-level factor and input shares across countries. I exploit the World Input-Output Database to calculate country-specific industry-level shares and find that the shares are not particularly similar across countries.[13] I allow input costs to vary by industry and not use, implying that Heckscher-Ohlin motives for trade exist only across industries. This decision is driven primarily by data availability. Use-varying costs would require labor, capital, and input shares that vary by use, and to my knowledge this data does not exist.

Ricardian comparative advantage at the end-use level enters through the productivity parameter $z_i^{k(u)}(l)$. Each industry k in country n produces a continuum of goods indexed by l on $[0, 1]$ for intermediate use and for final use. In country i, industry k's efficiency in producing a good for end use u is given by $z_i^{k(u)}(l)$. Iceberg trade costs are given by $\tau_{ni}^{k(u)}$. The unit cost of a good l produced by industry k in country i for end use u in country n is then $p_{ni}^{k(u)}(l) = c_i^k \tau_{ni}^{k(u)} / z_i^{k(u)}(l)$. Markets are perfectly competitive, so $p_{ni}^{k(u)}(l)$ is the price that buyers in country n would pay if the good were bought from country i. Instead, buyers shop around the world and purchase the good from the country with the lowest price. The price actually paid is then $p_n^{k(u)}(l) = \min \left\{ p_{ni}^{k(u)}(l); i = 1, \ldots, N \right\}$. Facing these prices, buyers of end-use u goods in country n purchase amounts of industry k goods to maximize a CES objective function. The price index for the CES objective function is $p_n^{k(u)} = \left[\int_0^1 p_n^{k(u)}(l)^{1-\sigma} \, \mathrm{d}l \right]^{1/(1-\sigma)}$, where σ is the elasticity of substitution between goods.

4.2 Technology

The efficiency parameter $z_i^{k(u)}(l)$ is the realization of a random variable drawn from a Fréchet distribution $F_i^{k(u)}(z) = e^{-T_i^{k(u)} z^{-\theta}}$. The parameter $T_i^{k(u)}$ governs the average efficiency with which goods are produced, and a higher value of $T_i^{k(u)}$ implies a higher level of technology.

[13] The coefficient of variation across countries within an industry (taking the average coefficient of variation across all industries) is 0.37 for labor shares and 0.55 for capital shares. For input shares—looking only at the diagonal entries to get a sense of variation in the shares of the most important input—this measure is 0.66.

Variation in end use within country and industry implies that, though a country may have an advantage in producing an industry k good for intermediate use, it may not be well suited to producing the industry k good for final consumption. We can therefore think of production of the industry k good as being tailored to suit the needs of a particular end use. The parameter θ governs the spread of the distribution; lower values imply more variation. More variation in efficiency draws (lower θ) increases the likelihood that technological advantage will overcome high production or transport costs, implying that trade flows will be more influenced by Ricardian comparative advantage.[14]

4.3 Consumption

Consumers have CES preferences over final goods produced by each industry k with elasticity of substitution σ, and Cobb-Douglas preferences over industries. The share of final consumption expenditure on each industry is $\eta_i^{F,k}$, with $\sum_k \eta_i^{F,k} = 1$.

4.4 Prices

The technology distribution and the CES price index (for consumers and buyers of intermediates) yield a closed form expression for prices in each destination country n that vary by industry k and end use u:

$$p_n^{k(u)} = \gamma \left[\sum_{i=1}^{N} T_i^{k(u)} (c_i^k \tau_{ni}^{k(u)})^{-\theta} \right]^{-1/\theta}, \tag{12}$$

[14]It is possible to embed correlation across end use within industries, resulting in the joint distribution $F_i^k(\mathbf{z}) = \exp\left\{ - \left[\sum_u \left(T_i^{k(u)} z^{-\theta} \right)^{1/\rho} \right]^{\rho} \right\}$, where $\mathbf{z}$ is the vector $[z_i^{I,k}, z_i^{F,k}]$ and ρ is a measure of correlation that rises as correlation decreases, with $0 < \rho \leq 1$. The parameter ρ is not separately identifiable from θ, and introducing correlation (low ρ) reduces the strength of comparative advantage in the same way that higher θ reduces the strength of comparative advantage.

where $\gamma = \left[\Gamma\left(1 + \frac{1-\sigma}{\theta}\right)\right]^{1/(1-\sigma)}$ and Γ is the gamma function.[15] Prices in country n are a function of its access $(\tau_{ni}^{k(u)})$ to the technology and costs of all countries i.

4.5 Trade

The probability that industry k in country i is the lowest-cost provider of good l for end use u in country n is $\pi_{ni}^{k(u)} = T_i^{k(u)} \left(\frac{\gamma c_i^k \tau_{ni}^{k(u)}}{p_n^{k(u)}}\right)^{-\theta}$.[16] Because there is a continuum of goods, $\pi_{ni}^{k(u)}$ is also the fraction of goods that end use u in country n buys from industry k in country i. Further, the distribution of minimum prices is invariant to the source country, so the average price per good is also invariant to the source. This means that $\pi_{ni}^{k(u)}$ is the fraction of country n, end use u expenditure on industry k goods that come from country i:

$$\pi_{ni}^{k(u)} = \frac{X_{ni}^{k(u)}}{X_n^{k(u)}} = T_i^{k(u)} \left(\frac{\gamma c_i^k \tau_{ni}^{k(u)}}{p_n^{k(u)}}\right)^{-\theta}, \tag{13}$$

where $X_n^{k(u)}$ is total spending on industry k goods by end use u in country n, and $X_{ni}^{k(u)}$ is spending on the goods that come from country i. A destination country will purchase a larger share of its industry k, end-use u requirements from a country with a higher technology level, lower costs, or with which it has lower bilateral trade costs. A high price in the destination country increases the share that the country will purchase from a given origin country relative to a destination country with a lower price.

[15]The efficiency parameter $z_i^{k(u)}(l)$ is the realization of the random variable $Z_i^{k(u)}$, so the delivered price of a good $p_{ni}^{k(u)}(l)$ is a realization of the random variable $P_{ni}^{k(u)} = c_i^k \tau_{ni}^{k(u)} / Z_i^{k(u)}$, and the lowest price is a realization of $P_n^{k(u)} = \min\left\{P_{ni}^{k(u)}; i = 1, \ldots, N\right\}$. Substituting the expression for $P_{ni}^{k(u)}$ into the technology distribution yields a distribution of prices $G_{ni}^{k(u)}(p) = 1 - F_i^{k(u)}(c_i^k \tau_{ni}^{k(u)}/p) = 1 - e^{-T_i^{k(u)}(c_i^k \tau_{ni}^{k(u)})^{-\theta} p^{\theta}}$. Buyers purchase the good from the country with the lowest price, so the price distribution is the distribution of minimum prices: $G_n^{k(u)}(p) = 1 - \prod_{i=1}^N [1 - G_{ni}^{k(u)}(p)] = 1 - e^{-\Phi_n^{k(u)} p^{\theta}}$, where $\Phi_n^{k(u)} = \sum_{i=1}^N T_i^{k(u)} (c_i^k \tau_{ni}^{k(u)})^{-\theta}$. Substituting this distribution into the CES price index yields the expression for $p_n^{k(u)}$.

[16]This probability is $\Pr\left[p_{ni}^{k(u)}(l) \leq \min\left\{p_{ni'}^{k(u)}(l); i' \neq i\right\}\right] = \int_0^\infty \prod_{i' \neq i} [1 - G_{ni'}^{k(u)}(p)] \, \mathrm{d}G_{ni}^{k(u)}(p)$. Substituting the distribution of prices $G_{ni}^{k(u)}$ yields the expression shown in the equation.

4.6 Market clearing

Total expenditure by country n on industry k goods X_n^k can be divided into expenditure on intermediates $X_n^{I,k}$ and expenditure on final goods $X_n^{F,k}$: $X_n^k = X_n^{I,k} + X_n^{F,k}$, and we can allocate intermediate and final expenditure to each origin country i using the trade shares $\pi_{ni}^{k(u)}$:

$$X_{ni}^k = \pi_{ni}^{I,k} X_n^{I,k} + \pi_{ni}^{F,k} X_n^{F,k}. \tag{14}$$

Goods markets clear, so the value of industry output Q_i^k equals the sum of expenditure by all countries n on industry k goods from country i: $Q_i^k = \sum_{n=1}^N X_{ni}^k$. Substituting (**??**) into the goods market clearing equation, we have:

$$Q_i^k = \sum_{n=1}^N \left(\pi_{ni}^{I,k} X_n^{I,k} + \pi_{ni}^{F,k} X_n^{F,k} \right). \tag{15}$$

Recalling the Cobb-Douglas production structure, equilibrium industry expenditures on labor and capital are a constant share of industry output:

$$w_n L_n^k = \alpha_n^k \beta_n^k Q_n^k \text{ and } r_n K_n^k = \iota_n^k \beta_n^k Q_n^k, \tag{16}$$

where L_n^k and K_n^k are the industry demands for labor and capital. Factor markets clear, so $\sum_k L_n^k = L_n$ and $\sum_k K_n^k = K_n$. Industry expenditure on intermediates is a fraction $1 - \beta_n^k$ of industry output, so we can write expenditure on industry k intermediates as a function of output in all industries k' using the input shares $\eta_n^{k',k}$:

$$X_n^{I,k} = \sum_{k'} \eta_n^{k',k} (1 - \beta_n^{k'}) Q_n^{k'}. \tag{17}$$

I do not require that trade is balanced. Denote S_n as the exogenous trade surplus of country n, with $\sum_n S_n = 0$ and $S_n = \sum_k S_n^k$. The industry-level trade surplus S_n^k is output minus expenditure, $S_n^k = Q_n^k - X_n^k$, so we can write equation (??) as:

$$X_n^{I,k} = \sum_{k'} \eta_n^{k',k}(1-\beta_n^{k'})(X_n^{k'} + S_n^{k'}). \tag{18}$$

Final consumption expenditure X_n^F equals national income Y_n, the sum of payments to labor and capital across all industries, minus the trade surplus S_n:

$$X_n^F = Y_n - S_n = \sum_k (w_n L_n^k + r_n K_n^k) - S_n. \tag{19}$$

Final consumption expenditure is allocated to each industry k by consumption shares $\eta_n^{F,k}$, so $X_n^{F,k} = \eta_n^{F,k} X_n^F$. This equation, and equations (??), (??), and (??) imply that we can write expenditure on industry k intermediates $X_n^{I,k}$ and expenditure on industry k final goods $X_n^{F,k}$ as functions of payments to the factors of production. That is,

$$X_n^{I,k} = \sum_{k'} \frac{\eta_n^{k',k}(1-\beta_n^{k'})}{\alpha_n^{k'}\beta_n^{k'}} w_n L_n^{k'} \tag{20}$$

and

$$X_n^{F,k} = \eta_n^{F,k} \sum_k (w_n L_n^k + r_n K_n^k - S_n^k). \tag{21}$$

Substituting equations (??) and (??) into (??), we can write:

$$Q_i^k = \sum_{n=1}^{N} \left[\pi_{ni}^{I,k} \left(\sum_{k'} \frac{\eta_n^{k',k}(1-\beta_n^{k'})}{\alpha_n^{k'}\beta_n^{k'}} w_n L_n^{k'} \right) + \pi_{ni}^{F,k} \eta_n^{F,k} \sum_k (w_n L_n^k + r_n K_n^k - S_n^k) \right]. \tag{22}$$

This equation, along with the cost and price equations (??)-(??), the trade share equation (??), and the factor market clearing and trade balance conditions, characterizes the solution. The parameters are α_n^k, ι_n^k, β_n^k, $\eta_n^{k,k'}$, $T_n^{k(u)}$, $\tau_{ni}^{k(u)}$, L_n, K_n, S_n, and θ. The model solves for costs c_n^k, wages w_n, rental rates r_n, prices $p_n^{k(u)}$, trade shares $\pi_{ni}^{k(u)}$, industry demands for labor and capital, L_n^k and K_n^k, and each industry-level trade surplus S_n^k.

5 Estimation

In this section I describe the procedure that I use to estimate and recover the parameters of the model. I use the estimated parameters to solve the model and to quantify the contribution of end-use variation to the gains from trade (Section ??). I also use the parameter estimates to understand the extent to which intermediate relative to final technology, trade costs, and prices are related to a country's income level (Section ??).

5.1 Deriving the estimating equation

The trade share equation (??) forms the basis of the estimation procedure. I follow Levchenko and Zhang (2013) to estimate the technology and trade cost parameters. I begin by normalizing the trade share equation by its domestic counterpart $\pi_{nn}^{k(u)}$. Dividing by the domestic trade share eliminates prices $p_n^{k(u)}$ and clearly illustrates comparative advantage: a country will import a larger share than it purchases domestically if the exporting country has an overall productivity and cost advantage, inclusive of trade costs (which are normalized to one in the domestic country):

$$\frac{\pi_{ni}^{k(u)}}{\pi_{nn}^{k(u)}} = \frac{T_i^{k(u)}}{T_n^{k(u)}} \left(\frac{c_i^k \tau_{ni}^{k(u)}}{c_n^k} \right)^{-\theta}. \tag{23}$$

Log-linearizing, this equation becomes

$$\ln \left(\frac{\pi_{ni}^{k(u)}}{\pi_{nn}^{k(u)}} \right) = \ln \left(T_i^{k(u)} \left(c_i^k \right)^{-\theta} \right) - \ln \left(T_n^{k(u)} \left(c_n^k \right)^{-\theta} \right) - \theta \ln \tau_{ni}^{k(u)}.^{17} \tag{24}$$

[17] Taking logs drops zeros from the estimation. I discuss dropped observations in Section ??.

The first two terms on the right hand side of the equation measure the origin and destination country's technology and cost advantage for producing industry k goods for end use u. I estimate the size of this advantage using fixed effects $S_i^{k(u)}$ and $S_n^{k(u)}$. Next, I specify a functional form for the trade cost parameter $\tau_{ni}^{k(u)}$ using trade cost proxies that are standard in the gravity literature: distance, presence of a shared border, and common language. Log trade costs are given by

$$\ln \tau_{ni}^{k(u)} = \left(d^{k(u)}\right)_m + b^{k(u)} + l^{k(u)} + ex_i^{k(u)}. \tag{25}$$

where $\left(d^{k(u)}\right)_m$ is the effect of lying in distance interval m, $b^{k(u)}$ is the effect of having a shared border, and $l^{k(u)}$ is the effect of sharing a language. The dummy variable associated with each effect is suppressed to simplify notation. The distance intervals in miles, following Eaton and Kortum, are: [0,375), [375, 750), [750, 1500), [1500,3000), [3000,6000), and [6000, max]. I also include an exporter fixed effect $ex_i^{k(u)}$; Waugh (2010) shows that exporter fixed effects, as opposed to importer fixed effects, produce estimates that are more consistent with the observed pattern of prices and country incomes. Substituting the trade cost specification (**??**) into equation (**??**), replacing the technology and cost advantage terms with fixed effects, and incorporating an error term $\varepsilon_{ni}^{k(u)}$, we arrive at the estimating equation:

$$\ln\left(\frac{\pi_{ni}^{k(u)}}{\pi_{nn}^{k(u)}}\right) = S_i^{k(u)} - S_n^{k(u)} - \theta\left(d^{k(u)}\right)_m - \theta b^{k(u)} - \theta l^{k(u)} - \theta ex_i^{k(u)} + \varepsilon_{ni}^{k(u)}. \tag{26}$$

The fixed effects $S_i^{k(u)}$ and $S_n^{k(u)}$ measure the same object—the technology-adjusted unit cost—so I restrict them to be symmetric. That is, $S_i^{k(u)} = S_n^{k(u)}$ for all $i = n$. Further, the estimating equation reduces to an identity for observations in which $i = n$, so domestic flows are omitted. I estimate the equation using OLS and Poisson and Gamma pseudo-maximum likelihood (PML) methods. I perform the Poisson and Gamma PML estimation methods to incorporate zeros—estimating the equation in logs drops zero trade flows—and to address the problem posed by heteroskedasticity that arises in log-transformed regressions as discussed in Santos-Silva and Tenreyro (2006).[18]

5.2 Recovering the parameters

In this subsection I describe the method that I use to recover the values $T_i^{k(u)}$, $\tau_{ni}^{k(u)}$, and $p_i^{k(u)}$. These estimates are used to investigate the relationship between aspects of comparative advantage and a country's income level, and the technology and trade cost parameters are used to solve the model. Each step requires an estimate of θ, which I again take to be four.

Recall that the estimated fixed effect $S_i^{k(u)}$ measures the technology-adjusted unit cost:

$$S_i^{k(u)} = \ln\left(T_i^{k(u)}\left(c_i^k\right)^{-\theta}\right).^{19} \tag{27}$$

To find prices I follow the method of Shikher (2012) by substituting the exponentiated fixed effect $\exp\left(S_i^{k(u)}\right)$ into the domestic expenditure share equation and rearranging:

$$p_i^{k(u)} = \left(\frac{\pi_{ii}^{k(u)}}{\exp\left(S_i^{k(u)}\right)}\right)^{1/\theta}. \tag{28}$$

To recover the technology parameter $T_i^{k(u)}$, first construct unit costs c_i^k using the Cobb-Douglas functional form: $c_i^k = \left(w_i^{\alpha_i^k} r_i^{\iota_i^k}\right)^{\beta_i^k}\left(\rho_i^k\right)^{1-\beta_i^k}$. Wages, rental rates, and labor and capital shares are data from the World Input-Output Database, and the price of a bundle of intermediates $\rho_i^k = \prod_{k'}\left(p_i^{I,k'}\right)^{\eta_i^{k,k'}}$ is constructed using prices derived as described above. Extract $T_i^{k(u)}$ from the fixed effect $S_i^{k(u)}$ using this value of c_i^k and equation (**??**). The

[18]Santos-Silva and Tenreyro (2006) show that when the variance of the error term in a multiplicative model depends on the regressors, the expected value of the error term in the log-linearized model will also depend on the regressors.

[19]The fixed effects are estimated relative to a reference country, which I take to be the US, so all variables used in the recovery of the parameters are also transformed to be relative to the US.

trade cost parameters $\tau_{ni}^{k(u)}$ are constructed by exponentiating equation (??): $\ln \tau_{ni}^{k(u)} = \left(d^{k(u)}\right)_m + b^{k(u)} + l^{k(u)} + ex_i^{k(u)}$.[20]

6 Data and implementation

I estimate the parameters of the model using the World Input-Output Database (WIOD), a global input-output table that reports trade flows between 35 industries (both manufacturing and service classifications) and 40 countries (and a rest of world aggregate) for the years 1995 through 2009. The 40 countries comprise 85 percent of world trade and include 29 countries classified as high income and 11 classified as upper middle or lower middle income by the World Bank in 2007. The data set distinguishes the exporting country and industry and the importing country and industry.[21] Because I am interested in the distinction between intermediate and final use, I aggregate all industry-use categories to create the intermediate classification, and all final consumption, investment, and inventory categories to create the final end-use classification.[22]

In order to minimize the number of trade zeros while keeping the data as disaggregate as possible, I combine countries or industries that have zero industry output. This aggregation

[20] The US is also the reference country for the exporter fixed effect, so the trade cost estimates are, net of all bilateral components, relative to the cost to export from the US for each industry-end-use pair.

[21] WIOD distinguishes use by allocating HS 6-digit import flows from the UN COMTRADE database to end-use categories (intermediate, final consumption, and investment) using a correspondence based on the Broad Economic Categories (BEC) from the United Nations Statistics Division. When a product can reasonably be classified into more than one end-use category, weights are applied to divide the trade flow into the relevant categories. Services trade is taken from various sources (UN, Eurostat, and OECD), and is split into end-use categories using average use shares from import input-output tables from Eurostat. Within the intermediate, final consumption, and investment categories trade flows are allocated by proportionality assumption. See Timmer (2012) for a detailed discussion of the construction of the World Input-Output Database.

[22] In some country-by-industry observations, the change in inventories is negative, reflecting a decline in inventories, and large enough that the total final use value is negative. I handle negative inventories using the method of Costinot and Rodríguez-Clare (2013) (see the online appendix to their paper), which is to set negative inventories to zero, and recalculate the total output vector and matrix of intermediate flows using the identity $X = (I - A)^{-1}F$, where X is the total output vector, A is the matrix of direct input coefficients, and F is the final demand vector, with negative inventories set to zero and positive inventories left unchanged.

scheme eliminates all country-by-industry output zeros, and reduces the number of countries from 40 to 38 and the number of industries from 35 to 32. See Tables **??** and **??** for WIOD countries and industries and the aggregation scheme. I estimate the model for the year 2007 because it is the most recent year that fully predates the trade collapse, and because capital stocks are provided only for a limited set of countries in 2008 and 2009. I exclude the rest of world aggregate because of the difficulty to create distance, border, and shared language variables for this region. The dimensions of the final data set are 38 origin by 38 destination countries by 32 industries by 2 types of end use.

I use the Socio-Economic Accounts (SEA) that accompany the WIOD to construct wages, rental rates, and labor and capital shares. Wages are calculated as total labor compensation in a country (LAB) divided by the total number of hours worked by persons engaged (H_EMP). The rental rate is constructed by dividing total capital compensation (CAP) by the value of the capital stock (K_GFCF), which is converted from real to nominal values using the price index for gross fixed capital formation ($GFCF\_P$). Labor and capital compensation and the value of the capital stock are converted to US dollars using exchange rates provided by WIOD. Labor and capital shares are computed by dividing labor compensation (LAB) and capital compensation (CAP) by gross output (GO). Input shares are constructed directly from WIOD by dividing country-by-industry total expenditure on intermediates by country-by-industry expenditure on intermediates from a particular industry. I compute each country's trade surplus using WIOD, excluding trade with the rest of the world aggregate. I do this to achieve balanced "world" trade in the sample of countries that I use in the simulation. Per capita income, which is used to investigate the relationship between comparative advantage and a country's level of development in Section **??** is given by output-side real GDP at chained PPPs in 2005 US dollars (*rgdpo*) per person (*pop*) for the year 2007 from the Penn World Tables Version 8.0.

The estimation strategy requires taking the log of relative trade shares, so zeros are not included. In total, 5.9 percent of the relative trade share observations are zeros. The prevalence of zeros varies by industry, and is higher in service industries—10 percent in service industries and 1.7 percent in goods industries. Within industries, across end use, the proportions of zeros are very similar. This means that, to the extent that missing observations introduce bias in the OLS estimates, concerns should be less pronounced for within-industry, across-end use comparisons, which are the focus of this paper. Even if zeros do not pose a significant problem, estimating log-transformed regression equations will produce inconsistent estimates when heteroskedasticity is present. To account for zeros and this problem posed by heteroskedasticity, I estimate the model using Poisson and Gamma pseudo-maximum likelihood (PML) methods in addition to OLS. I follow the procedure outlined in Head and Mayer (2014) to determine which of the three sets of estimates are most reliable.

7 Results

In this section I discuss the choice of estimation method and use the parameter estimates to take a closer look at technology, trade costs, and prices by end use as they relate to income. I also describe the trade cost estimates by end use, and show that the estimates imply a Balassa-Samuelson effect.

7.1 Evaluating the estimation methods

Determining whether to use the OLS, Poisson PML, or Gamma PML estimates requires assessing the similarity of the estimates across models. Head and Mayer (2014) provide recommendations for three scenarios: (1) the parameter estimates across the three methods are similar, (2) Poisson and Gamma PML estimates are similar but distinct from the OLS estimates, (3) the Gamma and OLS coefficients are similar and the Poisson are smaller in absolute magnitude. To assess the similarity of the high number of estimates, I regress the set of estimates from one method on the set of estimates for the other methods and force the coefficient on the regressor to equal one, ensuring that a good fit signifies that the estimates are not just correlated, but also similar in magnitude.[23] The R-squared from each regression is reported in Table **??**. I report the R-squared for the trade cost coefficients (distance, border, and language), the fixed effects (competitiveness and exporter), and for all coefficients. The trade cost estimates are similar across models, and the OLS estimates are particularly close to both the Poisson and Gamma estimates: R-squared 0.84 and 0.81, respectively. The fixed effects are less similar and reduce the strength of the overall fit, but the R-squared remains close to or above 0.5 in each case; this points toward scenario (1) from Head and Mayer. Further, the Poisson and Gamma estimates are less similar to each other than the OLS estimates are to each of these methods (R-squared 0.48 versus 0.54 and 0.57), which does not favor scenario (2). Scatter plots that correspond to the R-squared calculations, provided in Figure **??**, depict the relationship between coefficients across models. Regarding scenario (3), the Gamma and OLS estimates are similar, but the Poisson estimates are not smaller in absolute magnitude. Table **??** shows the average absolute value of the estimate for each set of parameters, and the Poisson estimates are not systematically lower than the others. This points toward scenario (1), in which case the log-linear model is well specified and consistency of the estimates is not a concern. I proceed here with the OLS estimates, and all exercises performed using the Poisson and Gamma estimates are available upon request.

[23]The estimating equation produces 5,248 parameter estimates: there are $(i-1)*u*k$ competitiveness fixed effects $S_i^{k(u)}$, $(i-1)*u*k$ exporter fixed effects $ex_i^{k(u)}$, $m*u*k$ distance coefficients $\left(d^{k(u)}\right)_m$, $u*k$ border coefficients $b^{k(u)}$, and $u*k$ common language coefficients $l^{k(u)}$.

7.2 A closer look at comparative advantage

The exercise in Section **??** indicated that low income countries have a comparative disadvantage in intermediate relative to final goods, and that these countries pay relatively higher prices for intermediates. In this section I use the parameter estimates to investigate these relationships further.

Before assessing the relationship between comparative advantage at the end-use level and income, I first evaluate the relationship between the individual intermediate and final estimates and income. I separately regress the intermediate and final technology, trade cost, and price estimates on log per capita GDP and industry fixed effects. The estimating equation for the technology and price estimates is:

$$\ln \Upsilon_i^{k(u)} = \beta_0 + \beta_1 \ln GDP_i + \alpha^{k(u)} + \varepsilon_i^{k(u)}, \text{ for } u = \{I, F\}, \tag{29}$$

where $\Upsilon_i^{k(u)}$ represents technology $(T_i^{k(u)})^{1/\theta}$ (the mean of each Fréchet distribution) or price $p_i^{k(u)}$, $\alpha^{k(u)}$ are the fixed effects, and $\varepsilon_i^{k(u)}$ is the error term. I expect that β_1 will be positive in the technology and price regressions because higher income countries are on average more productive and pay higher wages, which imply higher input costs. For trade costs, which vary by origin and destination country, the estimating equation is:

$$\ln \tau_{ni}^{k(u)} = \beta_0 + \beta_1 \ln GDP_c + \alpha^{k(u)} + \varepsilon_{ni}^{k(u)}, \text{ for } u = \{I, F\} \text{ and } c = \{n, i\}, \tag{30}$$

where the subscript c on the variable $\ln GDP_c$ indicates whether trade costs are regressed on exporter or importer income. I expect β_1 to be negative in the trade cost regressions, reflecting better transport infrastructure and more open trade policies in higher income countries. I run the regressions for all industries together and for four broad industry classifications:

Agriculture, Mining, Manufacturing, and Services. Table ?? presents the results.[24] High income countries have higher average technology levels for both intermediates and final goods than low income countries in all categories except Mining. The coefficient on income in the price regressions is also positive in the majority of the regressions. It is notably not statistically different from zero in the intermediate Mining and Manufacturing categories, likely due to the very tradable nature of these goods and, in the case of Mining, the lack of a relationship between technology and income. The export trade cost regressions show that the cost to export is decreasing in income for all categories except intermediate Agriculture and Mining, perhaps reflecting trade policies in lower income countries that promote commodity exports. The estimates from the import trade cost regressions show that higher income countries also pay less to import than lower income countries. The relationship is less pronounced than it is for export trade costs, but it exists for all industry categories. The signs of the coefficients are as expected—positive for the technology and price regressions and negative for the trade cost regressions—in every specification that includes all industries and in the majority of the industry category specifications.

To evaluate comparative advantage at the end-use level, I next regress relative values of the estimates on income. The specifications are the same as above, except the left hand side is now the log of the ratio of the intermediate estimate to the final estimate. The estimating equation for technology and prices is:

$$\ln\left(\frac{\Upsilon_i^{I,k}}{\Upsilon_i^{F,k}}\right) = \gamma_0 + \gamma_1 \ln GDP_i + \alpha^k + \mu_i^k, \tag{31}$$

[24]The dependent variable is a function of estimates, so I have also followed the Lewis and Linzer (2005) FGLS method to account for sampling error in the estimation of the dependent variable, using bootstrapped standard errors of the technology, trade cost, and price estimates to construct the weights that are applied in the second-stage WLS regression. The Stata routine for the procedure *edvreg* does not allow clustered standard errors, and the standard errors are more conservative when they are clustered and the Lewis and Linzer approach is not used. For this reason I present the clustered standard error estimates rather than the Lewis and Linzer estimates.

and the estimating equation for trade costs is:

$$\ln\left(\frac{\tau_{ni}^{I,k}}{\tau_{ni}^{F,k}}\right) = \gamma_0 + \gamma_1 \ln GDP_c + \alpha^k + \mu_{ni}^k, \text{ for } c = \{n, i\}. \tag{32}$$

The exercise in Section **??** that related relative domestic expenditure shares to relative technology and relative prices showed that low income countries have a comparative disadvantage in the production of intermediates, and the data showed that the relative price of intermediates is higher in these countries. It is likely that these findings do not hold for every industry category, but I do expect broadly similar results—that γ_1 is positive in the technology regressions and negative in the price regressions. Given that relative prices are decreasing in income, it is reasonable to expect that it is more difficult for lower income countries to import intermediates relative to final goods, implying that γ_1 is negative in the import trade cost regression; the price data do not have implications for the export trade cost regressions, however. The results are shown in Table **??**. High income countries have an overall comparative advantage in intermediates that is driven by comparative advantage in the Agriculture and Manufacturing sectors. The export trade cost regression coefficients are significant and positive for Agriculture and Manufacturing, indicating that lower income countries are able to export intermediate goods in these industries at a relatively lower cost than final goods compared to high income countries. The coefficients from the import trade cost regressions are mostly negative, indicating that low income countries have relatively more difficulty importing intermediates than final goods relative to high income countries. Relative prices are negatively related to income in all categories. This is consistent with the aggregate data, and with the fact that low income countries have a comparative disadvantage in intermediates and that it costs these countries relatively more to import intermediates. Recalling equation (**??**), prices are a function of the states of technology around the world and the importing country's access to these technologies via trade costs. If low income countries are not productive in intermediates and pay more to import them, they will pay a higher overall price.

7.3 Trade costs

Table **??** takes a closer look at trade costs. Each column shows the average coefficient across industries for intermediates and final use—for all industries, goods, and services. The familiar gravity result that trade decreases with distance and increases with the presence of a shared border and common language holds up by end use, and for both goods and services classifications. Across all industries, final goods and services are less tradable than intermediates, and the size of the barriers are large. The average implied effect on cost at a distance of [1500,3000) miles is 293 percent for final goods and services and 209 percent for intermediates with $\theta = 4$.[25] Not surprisingly, services are much less tradable than goods, and the result that final use goods or services tend to be less tradable than their intermediate counterparts holds up within these classifications (with the exception of the two furthest distance intervals for goods), and particularly so for services. This reflects the fact that final services (restaurant services or haircuts, for example) must often be consumed at the location of production, but intermediate services (financial services or information technology) need not.

7.4 Balassa-Samuelson effect

The results in Tables **??**, **??**, and **??** provide evidence of a Balassa-Samuelson effect, which says that countries with a higher productivity in the tradables sector will have a higher relative price of nontradables. I treat all goods as tradable, but final goods are comparatively less tradable than intermediates, as Table **??** shows. Greater tradability in intermediates

[25] The implied percentage effect on cost is $100(e^{-\hat{d}/\theta} - 1)$ for an estimated coefficient $\hat{d}$.

means that the prices of intermediates should be less variable across locations than the prices of final goods and services. Table **??** demonstrates this by reporting the standard deviation by end-use classification for industry-demeaned prices. Intermediate prices are less variable than final prices, and the same holds within goods and services classifications. Higher income countries have a higher technology level in intermediates, overall and for goods and services, so it follows that these countries will have a higher relative price of the less tradable good—or, equivalently, that lower income countries will have a higher relative price of the more tradable good, the intermediate (Table **??**).

8 Simulation

In this section I solve the full general equilibrium model to determine the effect that incorporating end-use variation has on the gains from trade relative to a model without end-use variation. The labor, capital, and input shares (α_n^k, β_n^k, and $\eta_n^{k,k'}$), size of the labor force (L_n), and capital stock (K_n) are constructed from WIOD as described in Section **??**. The technology and trade cost parameters ($T_i^{k(u)}$ and $\tau_{ni}^{k(u)}$) are estimated according to the procedure described in Section **??**, and θ is taken to be 4. The model solves for costs c_n^k, wages w_n, rental rates r_n, prices $p_n^{k(u)}$, trade shares $\pi_{ni}^{k(u)}$, industry demand for labor and capital, L_n^k and K_n^k, and each industry-level trade surplus S_n^k. I solve the model with and without end-use variation and compare the gains from trade. In the version without end-use variation, I re-estimate the parameters using trade data that is not distinguished by end use—that is, the left side of the estimating equation (**??**) is $\ln\left(\frac{\pi_{ni}^k}{\pi_{nn}^k}\right)$. The gains from trade relative to autarky for the models with and without end-use variation, and the discrepancy between the two, are shown in Tables **??** and **??**. In line with the literature, sectoral heterogeneity, input-output linkages, and multiple factors tend to raise the gains from trade: the gains from trade are larger under the full model without end-use variation than under the standard one-sector, one-factor model (recall Tables ?? and ??) on average and for the majority of countries. As Tables ?? and ?? show, end-use variation also raises the gains from trade. The gains from trade are 14.4 percent higher on average under the model with end-use variation than under the model without, and are higher for each income classification and country individually. Relative to the addition of other forms of heterogeneity, the contribution of end-use variation is sizeable. The gains from trade contributed by end-use variation alone are more than one-third the size of the gains from trade contributed by sectoral heterogeneity, input-output linkages, and multiple factors of production.[26] As in the analytical exercise, the contribution of end-use variation to the gains from trade is the largest for the lower income countries—26.3 percent on average for the upper middle income countries and 25.6 percent for the lower middle income countries, compared to 9.0 percent on average for the high income countries.

9 Conclusion

In this paper I show that a proper calculation of the gains from trade requires allowing for differences in the characteristics of intermediate and final goods trade. Domestic expenditure shares and prices vary by intermediate and final use, indicating the presence of productivity differences that generate gains from trade. This source of productivity differences has not previously been identified nor has it been explored as an avenue for the gains from trade. Distinguishing intermediate and final goods trade is of added importance because intermediates are used in the production of other goods and final goods are not—meaning that the gains from trade in intermediates, but not final goods, accumulate through the production process. I construct a simple model that allows for productivity differences in the production of intermediate and final goods, and show analytically that the gains from trade are always weakly

[26]The average gains from trade under the full model with end-use variation are 33.3 percent, compared to 29.7 percent for the full model without end-use variation, and 19.4 percent for the standard one-sector, one-factor model.

understated in a model that does not include this variation. To fully assess the size of the discrepancy, I construct a model that features variation in intermediate and final use at the industry level, linkages between industries, and multiple factors of production. Solving the model numerically, I find that the gains from trade are 14.4 percent higher on average under the end-use model. This size of this increase is significant: end-use variation alone accounts for more than one-third of the increase in the gains from trade contributed by these sources of heterogeneity. The discrepancy is larger for lower income countries. The gains from trade are 9.0 percent, 26.3 percent, and 25.6 percent higher on average for high income, upper middle income, and lower middle income countries, respectively, under the end-use model. Lower income countries benefit more from trade across intermediate and final use, and this appears to be related to the nature of comparative advantage. The parameter estimates show that low income countries have a comparative disadvantage in the production of intermediates; thus, opening to trade allows these countries to import intermediates—which generate cumulative gains from trade—from the more productive high income countries. Given their comparative disadvantage in intermediates, access to imported intermediates is particularly central to welfare in lower income countries. Despite this, the parameter estimates reveal that trade costs pose a disproportionate burden for trade in intermediates in low income countries: lower income countries pay relatively more to import intermediate goods than final goods compared to higher income countries. The combination of a comparative disadvantage in intermediates and a relatively higher cost to import intermediates results in a higher relative price of intermediates in low income countries. Higher prices of intermediates present an important policy challenge, as they limit the competitiveness of countries seeking greater access to international production networks. This study suggests that policies that target productivity improvements in intermediates and the lowering of barriers to trading intermediates may generate important welfare gains in low income countries.

10 Tables

Table 1: Determinants of the Gains from Trade Discrepancy: Domestic Expenditure Shares and Labor Shares

Income Classification	Overall	Final	Int.	Final/Int.	Labor Share
High	0.80	0.86	0.75	1.17	0.34
Upper Middle	0.83	0.87	0.79	1.11	0.31
Lower Middle	0.93	0.96	0.91	1.06	0.27

Notes: Income classifications are for the year 2007 and are defined by the World Bank, see Table **??**. Domestic expenditure shares, the ratios of final to intermediate domestic expenditure shares, and labor shares are simple averages across countries. Labor shares are computed as $labor\ compensation/(gross\ output - capital\ compensation)$.

Table 2: Gains from Trade: Comparison of End-Use and Standard Models

Income Classification	Standard	End Use	Discrepancy	Relative Elasticity
High	0.214	0.245	0.111	2.06
Upper Middle	0.178	0.204	0.151	2.27
Lower Middle	0.074	0.085	0.162	3.05

Notes: Income classifications are for the year 2007 and are defined by the World Bank, see Table **??**. Gains from trade are computed with $\theta = 4$, and are net gains from trade ($\widehat{W} - 1$). Gains from trade, the discrepancy between the two models (reported in percent), and the relative elasticities are averages across countries within each income classification.

Table 3: Determinants of the Gains from Trade Discrepancy: Domestic Expenditure Shares and Labor Shares

Country	Overall	Final	Int.	Final/Int.	Labor Share
Australia	0.92	0.93	0.92	1.01	0.36
Austria	0.77	0.83	0.71	1.17	0.37
Belgium	0.71	0.80	0.64	1.25	0.32
Bulgaria	0.72	0.77	0.68	1.15	0.22
Brazil	0.96	0.97	0.94	1.04	0.37
Canada	0.84	0.87	0.81	1.08	0.39
China	0.93	0.96	0.92	1.04	0.17
Cyprus, Luxembourg, & Malta	0.58	0.77	0.46	1.65	0.25
Czech Republic	0.74	0.81	0.70	1.15	0.24
Germany	0.82	0.86	0.79	1.10	0.37
Denmark	0.78	0.85	0.70	1.22	0.38
Spain	0.87	0.90	0.85	1.06	0.34
Estonia	0.74	0.80	0.69	1.16	0.31
Finland	0.82	0.89	0.77	1.15	0.33
France	0.88	0.91	0.85	1.07	0.38
United Kingdom	0.88	0.90	0.86	1.04	0.40
Greece	0.84	0.89	0.75	1.19	0.44
Hungary	0.67	0.80	0.57	1.41	0.29
Indonesia	0.93	0.96	0.89	1.07	0.33
India	0.94	0.96	0.91	1.06	0.32
Ireland	0.68	0.80	0.60	1.33	0.29
Italy	0.89	0.91	0.87	1.05	0.35
Japan	0.95	0.96	0.94	1.03	0.37
Korea	0.88	0.92	0.85	1.08	0.31
Lithuania	0.74	0.80	0.67	1.19	0.36
Latvia	0.78	0.80	0.75	1.06	0.31
Mexico	0.86	0.92	0.76	1.22	0.30
Netherlands	0.78	0.86	0.70	1.22	0.36
Poland	0.81	0.86	0.77	1.12	0.29
Portugal	0.83	0.85	0.80	1.06	0.36
Romania	0.81	0.85	0.76	1.12	0.36
Russia	0.91	0.89	0.92	0.97	0.36
Slovak Republic	0.70	0.80	0.62	1.28	0.19
Slovenia	0.72	0.79	0.66	1.19	0.34
Sweden	0.80	0.86	0.75	1.16	0.36
Turkey	0.90	0.93	0.86	1.09	0.25
Taiwan	0.79	0.86	0.74	1.17	0.29
United States	0.94	0.95	0.92	1.03	0.42

Notes: Labor shares are computed as *labor compensation*/(*gross output* − *capital compensation*).

Table 4: Gains from Trade: Comparison of End-Use and Standard Models

Country	Standard	End Use	Discrepancy	Relative Elasticity
Australia	0.059	0.061	0.019	1.80
Austria	0.195	0.215	0.103	1.71
Belgium	0.303	0.337	0.113	2.12
Bulgaria	0.448	0.505	0.126	3.52
Brazil	0.030	0.035	0.156	1.73
Canada	0.117	0.125	0.073	1.60
China	0.108	0.119	0.094	4.93
Cyprus, Luxembourg, and Malta	0.730	0.898	0.230	2.99
Czech Republic	0.376	0.405	0.077	3.20
Germany	0.139	0.148	0.069	1.69
Denmark	0.182	0.206	0.128	1.63
Spain	0.106	0.114	0.077	1.95
Estonia	0.275	0.306	0.112	2.26
Finland	0.157	0.176	0.118	2.02
France	0.087	0.095	0.089	1.66
United Kingdom	0.083	0.087	0.044	1.47
Greece	0.106	0.132	0.248	1.30
Hungary	0.410	0.495	0.207	2.45
Indonesia	0.059	0.071	0.197	2.06
India	0.054	0.064	0.195	2.16
Ireland	0.396	0.455	0.149	2.48
Italy	0.087	0.093	0.069	1.90
Japan	0.035	0.038	0.077	1.71
Korea	0.105	0.114	0.078	2.20
Lithuania	0.232	0.266	0.149	1.77
Latvia	0.222	0.235	0.059	2.19
Mexico	0.138	0.198	0.436	2.32
Netherlands	0.186	0.211	0.134	1.76
Poland	0.193	0.215	0.115	2.44
Portugal	0.137	0.147	0.067	1.78
Romania	0.162	0.181	0.114	1.81
Russia	0.068	0.065	-0.048	1.74
Slovak Republic	0.593	0.731	0.232	4.14
Slovenia	0.270	0.295	0.093	1.94
Sweden	0.166	0.183	0.098	1.79
Turkey	0.108	0.136	0.253	2.92
Taiwan	0.224	0.251	0.119	2.50
United States	0.039	0.042	0.069	1.41

Notes: Gains from trade are computed using the domestic expenditure and labor shares reported in Table **??** with $\theta = 4$, and are net gains from trade ($\widehat{W} - 1$). The discrepancy is the percent difference across the two models.

Table 5: List of Countries

Country	Abbreviation	Income Classification, 2007
Australia	AUS	High
Austria	AUT	High
Belgium	BEL	High
Bulgaria	BGR	Upper Middle
Brazil	BRA	Upper Middle
Canada	CAN	High
China	CHN	Lower Middle
Cyprus, Luxembourg, and Malta	CYP-LUX-MLT	High
Czech Republic	CZE	High
Germany	DEU	High
Denmark	DNK	High
Spain	ESP	High
Estonia	EST	High
Finland	FIN	High
France	FRA	High
United Kingdom	GBR	High
Greece	GRC	High
Hungary	HUN	High
Indonesia	IDN	Lower Middle
India	IND	Lower Middle
Ireland	IRL	High
Italy	ITA	High
Japan	JPN	High
Korea	KOR	High
Lithuania	LTU	Upper Middle
Latvia	LVA	Upper Middle
Mexico	MEX	Upper Middle
Netherlands	NLD	High
Poland	POL	Upper Middle
Portugal	PRT	High
Romania	ROM	Upper Middle
Russia	RUS	Upper Middle
Slovak Republic	SVK	High
Slovenia	SVN	High
Sweden	SWE	High
Turkey	TUR	Upper Middle
Taiwan	TWN	High
United States	USA	High

Notes: This table shows the list of countries, and their abbreviations and 2007 income classifications, included in the World Input-Output Database. Income classifications are determined by GNI per capita thresholds set by the World Bank. The thresholds, in US dollars, for Lower Middle, Upper Middle, and High income countries, respectively, are: \$936-\$3,705; \$3,706-\$11,455, and > \$11,455.

Table 6: List of Industries

NACE Code	Description	Classification	Aggregation
AtB	Agriculture, Hunting, Forestry and Fishing	Agriculture	AtB
C	Mining and Quarrying	Mining	C
15t16	Food, Beverages and Tobacco	Manufacturing	15t16
17t18	Textiles and Textile Products		17t18
19	Leather, Leather and Footwear		19
20	Wood and Products of Wood and Cork		20
21t22	Pulp, Paper, Paper, Printing and Publishing		21t22
23	Coke, Refined Petroleum and Nuclear Fuel		23
24	Chemicals and Chemical Products		24
25	Rubber and Plastics		25
26	Other Non-Metallic Mineral		26
27t28	Basic Metals and Fabricated Metal		27t28
29	Machinery, Nec		29
30t33	Electrical and Optical Equipment		30t33
34t35	Transport Equipment		34t35
36t37	Manufacturing, Nec; Recycling		36t37
E	Electricity, Gas and Water Supply	Services	E
F	Construction		F
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles		50, 51
51	Wholesale Trade and Commission Trade		
52	Retail Trade, Except of Motor Vehicles and Motorcycles		52
H	Hotels and Restaurants		H
60	Inland Transport		60
61	Water Transport		61
62	Air Transport		62
63	Other Supporting and Auxiliary Transport Activities		63
64	Post and Telecommunications		64
J	Financial Intermediation		J
70	Real Estate Activities		70
71t74	Renting of M&Eq and Other Business Activities		71t74
M	Education		M
N	Health and Social Work		N
L	Public Admin and Defence; Compulsory Social Security		L, O, P
O	Other Community, Social and Personal Services		
P	Private Households with Employed Persons		

Notes: This table shows the NACE code, description, classification, and aggregation scheme for industries in the World Input-Output Database.

Table 7: OLS, PPML, and GPML R-squared

	PPML vs. OLS	GPML vs. OLS	PPML vs. GPML
Trade Cost Estimates	0.84	0.81	0.66
Fixed Effects	0.43	0.50	0.40
Entire Regression	0.54	0.57	0.48

Notes: This table shows the R-squared from a regression of the coefficients from one estimation method against the coefficients from another estimation method with the coefficient on the independent variable constrained to be one.

Table 8: Average Absolute Value of Estimate

	OLS	PPML	GPML
Distance [0,375)	3.78	4.38	4.23
Distance [375,750)	4.02	4.87	4.64
Distance [750,1500)	4.40	5.40	5.18
Distance [1500,3000)	4.99	6.10	6.15
Distance [3000,6000)	6.30	6.22	6.92
Distance [6000,max]	7.02	6.84	7.53
Shared border	0.74	0.82	0.95
Shared language	0.32	0.44	0.57
Competitiveness Fixed Effect	1.51	1.67	2.01
Exporter Fixed Effect	3.72	3.30	3.75

Notes: This table shows the average value of the absolute value of the estimated coefficients across estimation methods.

Table 9: Regression of Log Parameters on Log GDP Per Capita, OLS Estimates

	Intermediate				Final			
	Coef.	Std. Err.	R-sq.	N	Coef.	Std. Err.	R-sq.	N
Technology								
All Industries	0.43***	(0.04)	0.53	1,184	0.37***	(0.04)	0.56	1,184
Agriculture	0.53***	(0.11)	0.26	37	0.34***	(0.12)	0.10	37
Mining	0.02	(0.16)	0.00	37	-0.10	(0.15)	0.01	37
Manufacturing	0.31***	(0.05)	0.40	518	0.22***	(0.05)	0.49	518
Services	0.55***	(0.06)	0.56	592	0.52***	(0.06)	0.48	592
Trade Costs (Exporter)								
All Industries	-0.33***	(0.09)	0.31	45,394	-0.37***	(0.10)	0.43	45,357
Agriculture	-0.14	(0.13)	0.02	1,444	-0.39***	(0.14)	0.09	1,444
Mining	-0.17	(0.15)	0.02	1,333	-0.36***	(0.13)	0.11	1,333
Manufacturing	-0.26***	(0.09)	0.18	20,068	-0.35***	(0.11)	0.24	20,105
Services	-0.41***	(0.11)	0.24	22,549	-0.38***	(0.11)	0.30	22,475
Trade Costs (Importer)								
All Industries	-0.09*	(0.05)	0.26	45,394	-0.09*	(0.05)	0.39	45,357
Agriculture	-0.13*	(0.07)	0.01	1,444	-0.15*	(0.08)	0.01	1,444
Mining	-0.15**	(0.07)	0.01	1,333	-0.07*	(0.04)	0.00	1,333
Manufacturing	-0.11*	(0.06)	0.13	20,068	-0.09*	(0.05)	0.15	20,105
Services	-0.07*	(0.04)	0.17	22,549	-0.08*	(0.04)	0.25	22,475
Prices								
All Industries	0.07**	(0.03)	0.65	1,184	0.12***	(0.03)	0.66	1,184
Agriculture	0.14***	(0.05)	0.23	37	0.31***	(0.04)	0.61	37
Mining	0.08	(0.06)	0.04	37	0.26***	(0.07)	0.23	37
Manufacturing	0.04	(0.03)	0.46	518	0.09***	(0.03)	0.51	518
Services	0.09**	(0.04)	0.61	592	0.13***	(0.04)	0.45	592

Notes: All regressions include industry fixed effects. The export trade cost estimates are obtained by regressing bilateral trade costs on exporter GDP and the import trade cost estimates are obtained by regressing bilateral trade costs on importer GDP. Standard errors are clustered at the country level. Significance at the one percent level is represented by ***, at the five percent level by **, and at the ten percent level by *.

Table 10: Regression of Log Relative Parameters on Log GDP Per Capita, OLS Estimates

	Intermediate/Final			
	Coef.	Std. Err.	R-sq.	N
Technology				
All Industries	0.06***	(0.02)	0.36	1,184
Agriculture	0.19***	(0.04)	0.26	37
Mining	0.12	(0.12)	0.04	37
Manufacturing	0.09***	(0.03)	0.15	518
Services	0.03*	(0.02)	0.46	592
Trade Costs (Exporter)				
All Industries	0.04*	(0.02)	0.41	45,283
Agriculture	0.25***	(0.07)	0.23	1,444
Mining	0.18	(0.13)	0.06	1,333
Manufacturing	0.09**	(0.04)	0.18	20,031
Services	-0.04*	(0.02)	0.48	22,475
Trade Costs (Importer)				
All Industries	-0.01*	(0.00)	0.41	45,283
Agriculture	0.01	(0.01)	0.00	1,444
Mining	-0.08**	(0.04)	0.01	1,333
Manufacturing	-0.02**	(0.01)	0.15	20,031
Services	0.00***	(0.00)	0.47	22,475
Prices				
All Industries	-0.05***	(0.02)	0.58	1,184
Agriculture	-0.17***	(0.04)	0.27	37
Mining	-0.18*	(0.10)	0.12	37
Manufacturing	-0.05**	(0.02)	0.30	518
Services	-0.04**	(0.01)	0.56	592

Notes: All regressions include industry fixed effects. The export trade cost estimates are obtained by regressing bilateral trade costs on exporter GDP and the import trade cost estimates are obtained by regressing bilateral trade costs on importer GDP. Standard errors are clustered at the country level. Significance at the one percent level is represented by ***, at the five percent level by **, and at the ten percent level by *.

Table 11: Trade Cost Components, OLS Estimates

	Coefficients					
	All Industries		Goods		Services	
Variable	Int.	Final	Int.	Final	Int.	Final
Distance [0,375)	-2.13	-3.15	0.93	0.64	-5.19	-6.93
Distance [375,750)	-3.22	-4.21	-0.36	-0.63	-6.07	-7.80
Distance [750,1500)	-3.87	-4.79	-1.33	-1.41	-6.41	-8.16
Distance [1500,3000)	-4.51	-5.47	-2.10	-2.26	-6.93	-8.68
Distance [3000,6000)	-5.90	-6.70	-3.80	-3.64	-8.01	-9.77
Distance [6000,max]	-6.66	-7.37	-4.48	-4.10	-8.84	-10.64
Shared border	0.76	0.73	0.78	0.69	0.73	0.76
Shared language	0.28	0.33	0.25	0.31	0.32	0.35

Notes: The trade cost components are the average distance, border, and language coefficients across industries from equation (**??**).

Table 12: Standard Deviation of Prices by End Use, OLS Estimates

	All Industries	Goods	Services
Intermediate	0.27	0.15	0.35
Final	0.34	0.24	0.41

Notes: Prices are demeaned by industry before computing the standard deviation.

Table 13: Gains from Trade Simulation: Comparison of End-Use and Standard Models

Income Classification	No End-Use	End-Use	Discrepancy
High	0.343	0.372	0.090
Upper Middle	0.245	0.312	0.263
Lower Middle	0.060	0.076	0.256

Notes: Income classifications are for the year 2007 and are defined by the World Bank, see Table **??**. Gains from trade are computed solving the full model (with and without end-use variation) with parameter values obtained as described in Sections **??** and **??**, and are net gains from trade ($\widehat{W} - 1$). Gains from trade and the discrepancy between the two models (reported in percent) are averages across countries within each income classification.

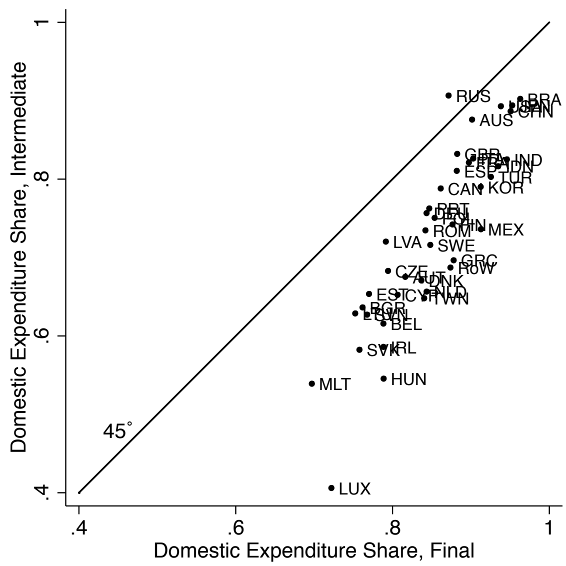
Table 14: Gains from Trade Simulation: Comparison of End-Use and Standard Models

Country	No End-Use	End-Use	Discrepancy
Australia	0.063	0.069	0.084
Austria	0.411	0.444	0.082
Belgium	0.988	1.052	0.064
Bulgaria	0.639	0.675	0.055
Brazil	0.020	0.029	0.434
Canada	0.283	0.299	0.058
China	0.079	0.104	0.321
Cyprus, Luxembourg, and Malta	1.172	1.315	0.122
Czech Republic	0.674	0.707	0.050
Germany	0.234	0.250	0.068
Denmark	0.421	0.439	0.043
Spain	0.160	0.172	0.073
Estonia	0.465	0.516	0.109
Finland	0.149	0.159	0.064
France	0.205	0.209	0.019
United Kingdom	0.135	0.145	0.075
Greece	0.213	0.242	0.133
Hungary	0.621	0.667	0.075
Indonesia	0.036	0.045	0.234
India	0.065	0.078	0.212
Ireland	0.477	0.501	0.051
Italy	0.118	0.153	0.295
Japan	0.039	0.045	0.135
Korea	0.185	0.201	0.087
Lithuania	0.263	0.332	0.264
Latvia	0.536	0.918	0.713
Mexico	0.108	0.121	0.119
Netherlands	0.377	0.399	0.059
Poland	0.255	0.274	0.074
Portugal	0.193	0.211	0.093
Romania	0.202	0.228	0.126
Russia	0.069	0.097	0.402
Slovak Republic	0.343	0.375	0.092
Slovenia	0.548	0.599	0.093
Sweden	0.198	0.203	0.026
Turkey	0.099	0.117	0.177
Taiwan	0.166	0.198	0.189
United States	0.059	0.064	0.096

Notes: Gains from trade are computed solving the full model (with and without end-use variation) with parameter values obtained as described in Sections **??** and **??**, and are net gains from trade ($\widehat{W}-1$). The discrepancy is the percent difference across the two models.

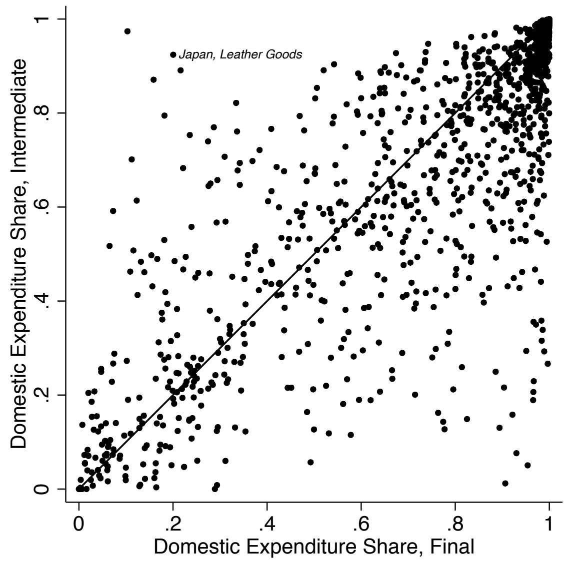
11 Figures

Figure 1: Country-Level Domestic Expenditure Share, Intermediate vs. Final



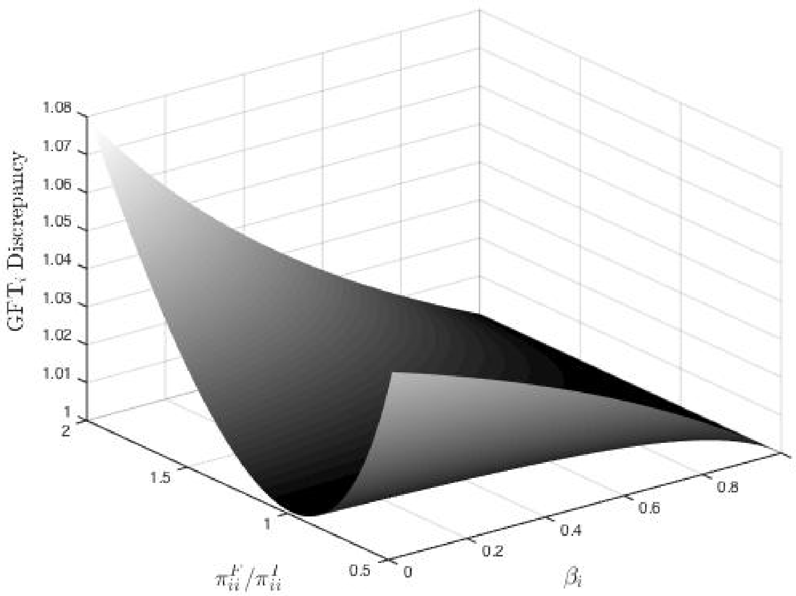
Notes: This figure plots the intermediate domestic expenditure share π_{ii}^I against the final domestic expenditure share π_{ii}^F for the 40 countries in the sample. The 45°-line is included for reference.

Figure 2: Country-by-Industry-Level Domestic Expenditure Share, Intermediate vs. Final



Notes: This figure plots the intermediate domestic expenditure share $\pi_{ii}^{I,k}$ against the final domestic expenditure share $\pi_{ii}^{F,k}$ for the 38x32 country-industry pairs in the sample. The 45°-line is included for reference.

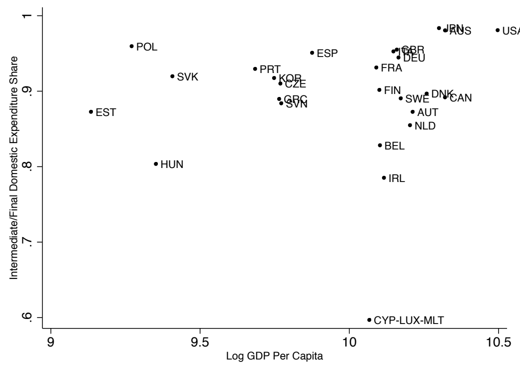
Figure 3: Gains from Trade Discrepancy, End-Use vs. Standard Model



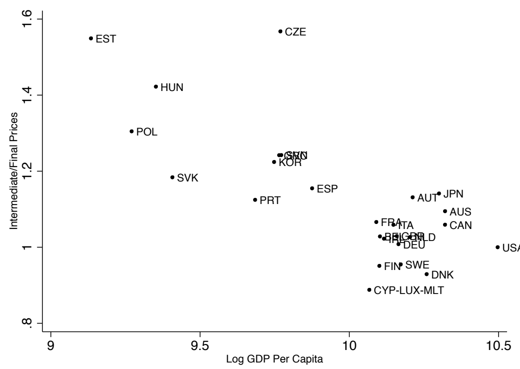
Notes: This figure plots the discrepancy between the end-use and standard gains from trade formulas given by equation (**??**) for $\theta = 4$.

Figure 4: Domestic Expenditure Share, Prices, and Comparative Advantage

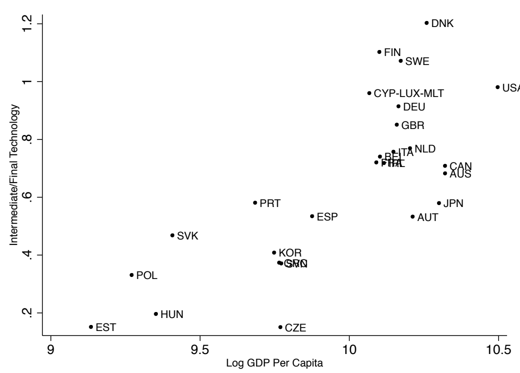
(a) Relative Domestic Expenditure Shares and Income



(b) Relative Prices and Income



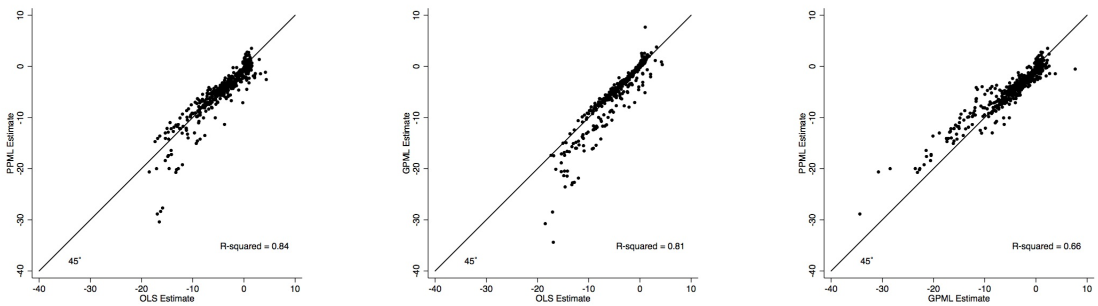
(c) Relative Technology and Income



Notes: This figure plots the ratio of country-level intermediate to final domestic expenditure shares (a), prices (b), and technology levels T_i^I/T_i^F implied by equation (**??**) (c) against log GDP per capita for the 27 countries with relative price data.

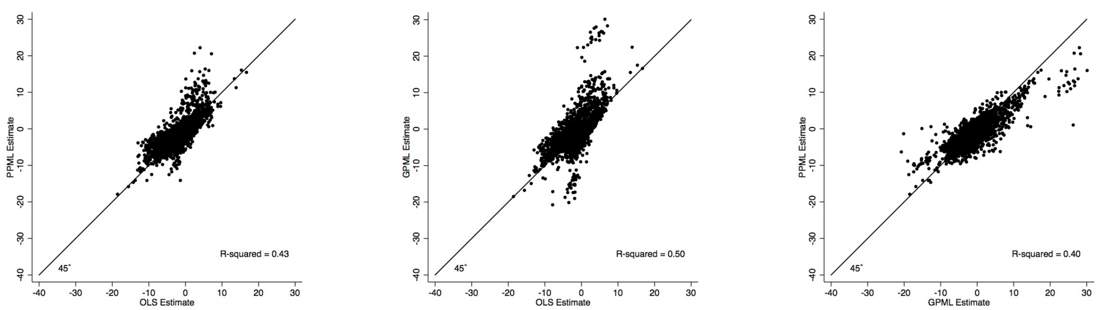
Figure 5: OLS vs. Poisson PML vs. Gamma PML

(a) Trade Cost Coefficients



Notes: This figure plots the estimated trade cost coefficients (distance, border, and language effects) for one estimation method (OLS, PPML, or GPML) against the same coefficients for another estimation method (OLS, PPML, or GPML). The 45°-line is provided for reference.

(b) Fixed Effects



Notes: This figure plots the estimated fixed effects (competitiveness and exporter) for one estimation method (OLS, PPML, or GPML) against the same coefficients for another estimation method (OLS, PPML, or GPML). The 45°-line is provided for reference.