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Gains from Trade: Does Sectoral Heterogeneity Matter?*

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Abstract

This paper assesses the quantitative importance of including sectoral heterogeneity in computing the gains from trade. Our framework draws from Caliendo and Parro (2015) and Alvarez and Lucas (2007) and has sectoral heterogeneity along five dimensions, including the elasticity of trade to trade costs, the value-added share, and the input-output structure. The key parameter we estimate is the sectoral trade elasticity, and we use the Simonovska and Waugh (2014) simulated method of moments estimator with micro price data. Our estimates range from 2.97 to 8.94, considerably lower than those obtained with the Eaton and Kortum (2002) price-based method. Our benchmark model is calibrated to 21 OECD countries and 20 sectors. We compute the gains from trade in our benchmark model, and in several re-calibrated versions of the model in which we eliminate one or more sources of sectoral heterogeneity. Our main result is that sectoral heterogeneity does not always lead to an increase in the gains from trade. There are two reasons for this. First, the magnitudes of our estimated sectoral trade elasticities are relatively high, while the magnitude of our estimated aggregate trade elasticity is low. All else equal, this will lead to higher gains for the aggregate, one-sector model. Second, the sectors with low trade elasticities (hence, implying high gains from trade) are not the sectors with low value-added shares and with high initial trade shares (which would magnify the gains). Hence, the sectoral heterogeneity in our calibrated model does not exert complementary gains from trade effects.

Keywords: gains from trade, estimated trade elasticities, simulated method of moments, sectoral heterogeneity, international price dispersion, multi-sector trade
JEL Classifications: F10, F11, F14, F17

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1 Introduction

What is the appropriate level of disaggregation and heterogeneity needed to compute the gains from international trade across a large set of countries? A great deal, it would seem, in order to obtain the most accurate calculation. One of the enduring contributions of Eaton and Kortum (2002) and Melitz (2003) is that their rich models with selection, multiple countries, and other dimensions, built on a foundation of classic trade mechanisms, are computationally tractable. A recent literature, largely inspired by Arkolakis, Costinot, and Rodriguez-Clare (2012), has employed such models, and other models, to examine the importance of disaggregation and heterogeneity in computing the gains from trade. However, no paper has done so in a systematic and comprehensive way, particularly with respect to trade elasticities.

The goal of this paper is to comprehensively and quantitatively assess whether more sectoral heterogeneity indeed delivers higher gains. We develop a multi-country, multi-sectoral trade model that draws from Caliendo and Parro (2015) and Alvarez and Lucas (2007), both of which stem from Eaton and Kortum (2002). In this class of models, as Caliendo and Parro (2015) discuss, the gains from trade can be divided into two terms. The first is the direct gains from increased trade. Within each sector, these gains are greater the larger the increase in trade, the lower the trade elasticity, and the smaller the value-added share. To the extent these three forces are positively correlated across sectors, the gains are larger, as well. The second is from intersectoral linkages. These linkages show up as changes in relative prices of inputs, mediated by their share in the production of the sectoral good. The more the relative price of inputs declines, the larger the gains. Accordingly, based on the interaction of these forces, the welfare gains from trade can be higher or lower when sectoral heterogeneity is considered. In order to ascertain quantitatively the gains from trade in different model settings, careful estimation and calibration of the parameters, as well as useful counterfactual simulations, are needed.

We estimate and calibrate the parameters of our 20-sector, 21-country model to match key features of the price, output, and trade data. A key contribution of our paper is that we estimate the elasticity of trade with respect to trade costs for each of 19 traded sectors using the simulated method of moments (SMM) methodology of Simonovska and Waugh (2015). This methodology builds on an estimation methodology with micro price-level data introduced by Eaton and Kortum (2002), but corrects the bias from a small sample of price observations.[1] The original Eaton and Kortum (hereafter, EK) estimator exploited a no-arbitrage condition to estimate trade costs. Essentially, with a sample of prices of individual goods comparable across countries, the trade cost between two countries must not be less than any of the price differences for any good across that pair of countries. In other words, if the sample is large enough, the trade cost should equal the maximum price difference. However, in small samples, Simonovska and Waugh (2015) show that estimating trade costs in this way leads to upwardly biased estimates of the trade elasticity. Simonovska and Waugh develop an SMM estimator to correct for that bias. To our knowledge, this is the first application of the Simonovska and Waugh SMM estimator to estimate the trade elasticity at the sector level.[2] We use the Eurostat surveys of retail prices, which covers 12 OECD countries and 19 three-digit ISIC traded good sectors for 1990.[3]

Our sectoral trade elasticity estimates range from 2.97 to 8.94; the median is 4.38. We also estimate the sectoral trade elasticities with the original Eaton and Kortum (EK) method and the minimum, maximum, and median elasticities are 4.26, 35.55, and 10.29. So, our SMM estimates are clearly lower, as SW obtained in their paper with a one-sector framework. In addition, as in SW, the "bias" is larger the smaller the sample size. For example, ISIC 352, Other chemicals, has a sample size of 4, while ISIC 311, Food products, has a sample size of 343. Our SMM estimates are similar across these two industries, 3.75 and 3.57, respectively, but the EK estimates are 11.93 and 4.28, respectively. These estimates are used in our calibrated model, which has 21 countries and 20 sectors (19 traded sectors and one non-traded goods sector). We calibrate the other parameters to match their data counterparts and/or to be consistent with sectoral outputs and trade flows.

With our calibrated model, we compute the gains from trade by comparing the welfare in our benchmark equilibrium relative to welfare in a counterfactual autarky equilibrium.

[1]Eaton, Kortum and Kramarz (2011) also employ this type of estimator.

[2]Simonovska and Waugh (2014b) go further by showing that, given the data on trade flows and micro-level prices, different models have different implied trade elasticities and welfare gains.

[3]See Crucini, Telmer, and Zachariadis (2005), for example.

Our benchmark calibrated model delivers gains from trade ranging from 0.38 percent in Japan to 9.59 percent in Ireland. The median gain in going from autarky to the calibrated equilibrium is 4.25 percent (Finland). We decompose our "benchmark" gains by sector, and we find that in most countries only a few sectors account for most of the welfare gains. In addition, we find that the direct trade effect is positive and the intersectoral linkage effect is negative in all countries. The presence of the non-traded goods sector is critical to this result. Labor plays a key role in non-traded goods production, and non-traded goods play a key role as inputs into traded goods. A trade cost shock will induce a response in wages that, through this non-traded goods channel, mitigate the effects of the original shock.

We then conduct two sets of counterfactual exercises to assess the role of sectoral heterogeneity. In the first set of exercises, we calibrate and estimate a one-sector model with no sectoral heterogeneity in trade elasticities, value-added shares, input-output structure, bilateral trade costs, and productivities. As part of this, we estimate the one-sector elasticity using the same methodology as above. We compare the gains from trade in this one-sector model with that from our benchmark model. We find that the gains from the benchmark model are typically slightly lower than in the one-sector model. This is our main result. When we investigate the sources of this result, we find that the relatively high estimated sectoral elasticities and the relatively low estimated one-sector elasticity plays a key role. If we replace our estimated one-sector elasticity with the median elasticity from the benchmark model, then the gains from trade in the benchmark model are about twice as large as in the one-sector model.

In the second set of exercises, we eliminate one source of sectoral heterogeneity at a time; in its place, we employ a homogeneous parameter that is common across all sectors. For example, we replace the estimated sectoral trade elasticities with a single elasticity common to all sectors. As in the first set of exercises, when we "reduce" heterogeneity, we re-calibrate the trade cost and productivities so that the model continues to be consistent with the output and trade data. We then compute the gains from trade and compare these gains to the benchmark model gains. When we replace our estimated sectoral trade elasticities with the median estimate (4.38), as well as when we replace the sectoral value-added shares with the average value, we find that the gains from trade are about the same compared to the benchmark model. In other words, including for sectoral heterogeneity in these particular cases does not lead to significantly larger gains. The primary reason for the similarities in gains is that the sectors that provide the greatest gains also happen to have trade elasticities that do not differ much from the median estimate, nor are they sectors associated with very low value-added shares. If sectors with low estimated trade elasticities are also sectors with low value-added shares, then, all else equal, sectoral heterogeneity would deliver larger gains from trade than a model with a common elasticity and/or value-added share across sectors. Similarly, when we impose a common input-output structure across all sectors, we find the gains are slightly smaller than in the benchmark model. All of these quantitative exercises imply that the interaction of the sectoral parameters and variables with each other does not deliver additional gains from trade.

Overall, we conclude from our quantitative exercises that heterogeneity does not necessarily imply larger gains from trade. This is consistent with the theory. As Caliendo and Parro (2015) show, the gains from trade is a non-linear function of the existing sectoral domestic expenditure shares, the sectoral trade elasticity, and the value-added shares, on the one hand, and the input-output structure and relative prices, on the other hand. In addition, a key reason for our main result is that we are using model-consistent estimates of our trade elasticities in both our benchmark model and our one-sector model.

Our paper is most closely related to Costinot and Rodriguez-Clare (2014), and Ossa (2015). Costinot and Rodriguez-Clare (2014) and Ossa (2015) compare the gains from multi-sector models to the gains from one-sector models, similar to our first set of exercises, except they essentially use an average sectoral elasticity as their one-sector elasticity, rather than an estimated one-sector elasticity. But, as discussed above, when we replace our estimated one-sector elasticity with the median of the sectoral elasticities, our results and theirs are qualitatively similar. We go further by examining the sources of heterogeneity one at a time. All of our results show that greater heterogeneity does not necessarily lead to greater gains, and are behind our overall nuanced conclusion that depending on the source of heterogeneity and on the nature of the exercise, the gains from trade in frameworks with increased heterogeneity can be larger or smaller.

Caliendo and Parro (2015) also evaluate the gains from trade in multi-sector versus one-sector models in the context of the gains from NAFTA. They find that the multi-sector model delivers larger gains. Our paper helps address the issue of whether their results extend to other contexts.Levchenko and Zhang (2014) is another related paper. The authors focus on heterogeneity arising from differences in comparative advantage across sectors. However, unlike our paper, they do not study the effects of heterogeneity in within sector comparative advantage, as captured by sector-specific $1/\theta$'s. Their main exercise involves assessing the ability of one-sector and multi-sector gains from trade formulas to capture the gains from trade in a calibrated multi-sector model. They find that the multi-sector formulas that allow for the most heterogeneity, and adjust for the importance of the non-traded sector, come the closest to matching the welfare gains from the calibrated model.

The rest of the paper is organized as follows. Section 2 lays out our model, and the following section provides our calibration and estimation methodology. Section 4 presents our results, including our elasticity estimates, our benchmark welfare gains, and our counterfactuals. Section 5 concludes.

2 Model

Our model draws from Alvarez and Lucas (2007) and Caliendo and Parro (2015), both of which extend Eaton and Kortum (2002). There are N countries, S sectors producing tradable goods, and one sector producing a single non-traded good.

2.1 Production

In each tradable goods sector $s \in S$ of country $i \in N$, there is a continuum of goods $x_i^s \in [0,1]$. Each good is produced by combining labor and tradable and non-tradable intermediate inputs with a Cobb-Douglas technology:

$$q_i^s\left(x^s\right) = z_i\left(x^s\right)^{-\theta^s}\left[l_i\left(x^s\right)\right]^{\beta^s}\left[\prod_{m=1}^{S+1} Q_i^m\left(x^s\right)^{\xi^{s,m}}\right]^{1-\beta^s}$$

where $z_i\left(x^s\right)$ is a random cost draw for good x_i^s from an exponential distribution - $\exp\left(\lambda_i^s\right)$. λ_i^s is a sector and country-specific productivity parameter. The $z_i\left(x^s\right)$'s are assumed to be independent across goods, sectors and countries. θ^s controls the impact of $z_i(x^s)$. $l_i(x^s)$ is the amount of labor used to produce good x of sector s in country i, and the amount of sector m composite good used as an intermediate input is denoted by $Q_i^m(x^s)$. The shares $\xi^{s,m}$ capture the input-output structure of production across sectors, and they satisfy $\sum_{m=1}^{S+1} \xi^{s,m} = 1$ for every sector s.

The individual goods in each sector are traded across countries. For a particular country-sector pair i,s, each of the continuum of individual goods is procured at the lowest price, and all of them are then combined via a constant elasticity of substitution (CES) aggregator to make a sectoral composite good C_i^s:

$$C_i^s = \left[\int \overline{q}_i^s(x^s)^{\frac{\eta^s-1}{\eta^s}} f^s(x^s)\, dx^s \right]^{\frac{\eta^s}{\eta^s-1}}$$

where $\overline{q}_i^s(x^s)$ is the amount of good x of sector s used to produce the composite good. The elasticity of substitution between the individual tradable goods of sector s is η^s. Given that the cost draws - $z_i(x^s)$'s -, characterizing goods in the continuum, are assumed to be independent across goods, sectors and countries, the joint density function of the shocks across countries is:

$$\left(\prod_{i=1}^{N} \lambda_i^s \right) \exp\left(-\sum_{i=1}^{N} \lambda_i^s z_i^s \right)$$

The non-traded sector's composite good is produced as follows:

$$C_i^{S+1} = C_i^N = A_i^N \left[l_i^N \right]^{\gamma} \left[\prod_{m=1}^{S+1} \left(Q_i^{N,m} \right)^{\phi^{N,m}} \right]^{1-\gamma} ,$$

where l_i^N is the labor used in the production of the non-traded composite good, $Q_i^{N,m}$ is the amount of sector m composite used as intermediate input, and the shares of $\phi^{N,m}$ satisfy $\sum_{m=1}^{S+1} \phi^{N,m} = 1$. A_i^N represents the TFP in non-traded sector.

2.2 Prices

We make the standard iceberg assumption - in order for country i to receive one unit of a good of sector s, country j must ship $\tau_{ij}^s > 1$ units. Given that the individual goods can be bought from domestic or foreign producers, the price of good x of sector s in country i is

$$p_i^s(x^s) = \min_j \left\{ B^s V_j^s z_j^s \left(x_j^s\right)^{\theta^s} \tau_{ij}^s \right\} \tag{2.1}$$

where V_i^s is an input bundle cost given by:

$$V_i^s = [w_i]^{\beta^s} \left[\prod_{m=1}^{S+1} (P_i^m)^{\xi^{s,m}} \right]^{1-\beta^s} \quad , \tag{2.2}$$

where w_i denotes wages, P_i^m denotes the price of Q_i^m, and B^s denotes a sector-specific constant.[4]

Properties of the exponential distribution imply that

$$p_i^s(x^s)^{\frac{1}{\theta^s}} \sim \exp\left\{ (B^s)^{\frac{-1}{\theta^s}} \sum_{j=1}^{N} \psi_{ij}^s \right\}$$

where

$$\psi_{ij}^s = \left(V_j^s \tau_{ij}^s\right)^{\frac{-1}{\theta^s}} \lambda_j^s \quad . \tag{2.3}$$

Since sector s composite good is produced using CES technology, the price of the sector s composite is

$$P_i^s = \left[\int_0^1 p_i^s(x^s)^{1-\eta^s} dx^s \right]^{\frac{1}{1-\eta^s}} \quad ,$$

which, given the distribution of $p_i^s(x^s)^{\frac{1}{\theta^s}}$, can be written as (see the Appendix for details)

$$P_i^s = A^s B^s \left(\sum_{j=1}^{N} \psi_{ij}^s \right)^{-\theta^s} \quad , \tag{2.4}$$

where A^s is a sector-specific constant.[5]

[4] $B^s = (\beta^s)^{-\beta^s} (1-\beta^s)^{-(1-\beta^s)} \left[\prod_{m=1}^{S+1} (\xi^{s,m})^{-\xi^{s,m}} \right]^{(1-\beta^s)}$

[5] $A^s = \left(\int_0^\infty u^{\theta^s(1-\eta^s)} \exp(-u)\, du \right)^{\frac{1}{1-\eta^s}}$ is a Gamma function.

The price of the non-traded composite good is:

$$P_i^N = E\frac{[w_i]^\gamma \left[\prod_{m=1}^{S+1} (P_i^m)^{\phi^{N,m}}\right]^{1-\gamma}}{A_i^N} \quad ,$$

which implies,

$$P_i^N = \left[E\frac{[w_i]^\gamma \left[\prod_{m=1}^{S} (P_i^m)^{\phi^{N,m}}\right]^{1-\gamma}}{A_i^N}\right]^{\frac{1}{1-\phi^{N,N}(1-\gamma)}} \quad , \tag{2.5}$$

where

$$E = \gamma^{-\gamma} (1-\gamma)^{-(1-\gamma)} \left(\prod_{m=1}^{S+1} \left(\phi^{N,m}\right)^{-\phi^{N,m}}\right)^{(1-\gamma)} \quad .$$

2.3 Consumption

In each country there is a representative household that derives utility from a final consumption good (Y_i).

$$U_i = Y_i \quad .$$

The final consumption good is a Cobb-Douglas aggregator of the sectoral composite goods.

$$Y_i = \prod_{m=1}^{S+1} \left(Y_i^{f,m}\right)^{\delta^{f,m}} \quad , \tag{2.6}$$

where $Y_i^{f,m}$ is the final consumption of sector m composite, and $\sum_{m=1}^{S+1} \delta^{f,m} = 1$. The price of the final good, therefore, is given by

$$P_i = \prod_{m=1}^{S+1} \left(\delta^{f,m}\right)^{-\delta^{f,m}} (P_i^m)^{\delta^{f,m}} \quad . \tag{2.7}$$

2.4 Market Clearing

We normalize labor in each country to 1. Then, the market clearing conditions for labor and sectoral composite goods are given by:

$$\sum_{s=1}^{S} \underbrace{\int_0^1 l_i^s(x^s)\,dx^s}_{l_i^s} + l_i^N \leq 1 \quad , i = 1, \ldots, N \quad ,$$

$$\sum_{m=1}^{S} \underbrace{\int_0^1 Q_i^{m,s}(x^s)\,dx^s}_{Q_i^{m,s}} + Q_i^{N,s} + Y_i^{f,s} \leq C_i^s \quad , i = 1, \ldots, N \ , \ s = i = 1, \ldots, S+1 \quad .$$

2.5 Trade Flows

We now derive an expression for trade shares that will be important for our quantitative work. Owing to properties of the exponential function, the probability that good x of sector s is exported by country j to country i is the same across all goods in that sector:[6]

$$\pi_{ij}^s(x^s) = \pi_{ij}^s = \frac{\psi_{ij}^s}{\psi_{ij}^s + \sum_{n \neq j} \psi_{in}^s} = \frac{\psi_{ij}^s}{\sum_{n=1}^{N} \psi_{in}^s} \quad . \tag{2.8}$$

Hence, the expenditure of country i on sector s goods of country j is

$$X_{ij}^s = \pi_{ij}^s X_i^s \quad ,$$

where X_i^s is the total per capita expenditure of country i on sector s goods. We use D_{ij}^s to denote the share of country j in country i's expenditure on sector s goods:

$$D_{ij}^s = \frac{X_{ij}^s}{X_i^s} = \pi_{ij}^s = \frac{\psi_{ij}^s}{\sum_{n=1}^{N} \psi_{in}^s} \quad .$$

Using (2.4), we can rewrite this expression as:

$$D_{ij}^s = (A^s B^s)^{-\frac{1}{\theta^s}} \left(\frac{V_j^s \tau_{ij}^s}{P_i^s} \right)^{\frac{-1}{\theta^s}} \lambda_j^s \tag{2.9}$$

[6] See EK for the derivation

which is decreasing in source country input bundle cost V_j^s and trade costs τ_{ij}^s and increasing in the productivity parameter λ_j^s.

2.6 Expenditure on Sectoral Goods, Wages and Labor Allocations

How is the per capita expenditure on a sector's goods determined? To see this, start with the market clearing condition for composite good of sector s and multiply both sides by its price. This yields

$$X_i^s = P_i^s C_i^s = \sum_{m=1}^{S} P_i^s Q_i^{m,s} + P_i^s Q_i^{N,s} + P_i^s Y_i^{f,s} \quad , \tag{2.10}$$

where the first term on the right hand side is the expenditure of all traded good sectors on sector s composite, the second term is the expenditure of the non-traded good sector on sector s composite, while the last term is final consumption expenditure on sector s composite. Due to Cobb-Douglas production technologies, these components of expenditure of sector s composite ($s = 1, \ldots, S+1$) are given by

$$P_i^s Y_i^{f,s} = \delta^{f,s} P_i Y_i = \delta^{f,s} w_i L_i \quad ,$$

$$P_i^s Q_i^{m,s} = (1-\beta^m)\,\xi^{m,s} \sum_{j=1}^{N} L_j X_j^m D_{ji}^m \ , \ m = 1, \ldots, S \quad ,$$

$$P_i^s Q_i^{N,s} = (1-\gamma)\,\phi^{N,s} L_i X_i^N \quad ,$$

where $X_i^N = P_i^N C_i^N$. Thus, the total expenditure on sector $s = 1, \ldots, S+1$ composite is given by

$$L_i X_i^s = \delta^{f,s} w_i L_i + (1-\gamma)\,\phi^{N,s} L_i X_i^N + \sum_{m=1}^{S} (1-\beta^m)\,\xi^{m,s} \sum_{j=1}^{N} L_j X_j^m D_{ji}^m \quad . \tag{2.11}$$

Wages are determined by using the balanced trade condition.

$$\sum_{s=1}^{S} \sum_{j=1}^{N} L_j X_j^s D_{ji}^s = \sum_{s=1}^{S} L_i X_i^s \quad . \tag{2.12}$$

Once we have the per capita expenditure on a sector's goods and the wage, labor allocation is derived from

$$L_i w_i l_i^s = \beta^s \sum_{j=1}^{N} L_j X_j^s D_{ji}^s \quad , \tag{2.13}$$

$$L_i w_i l_i^N = \gamma L_i X_i^N \quad . \tag{2.14}$$

2.7 Equilibrium

The competitive equilibrium is the sectoral composite good price indices ($\{P_i^s\}_{s=1}^S, P_i^N$), per capita expenditures on each sector's goods ($\{X_i^s\}_{s=1}^S, X_i^N$), wages (w_i), and labor allocations ($\{l_i^s\}_{s=1}^S, l_i^N$) that provide a solution to the system of equations - (2.4), (2.5), (2.9), (2.11), (2.12), (2.13), and (2.14).

2.8 Sources of Gains from Trade

What are the sources of gains from trade in our model with inter-sectoral linkages? Using (2.7) for the price of the final consumption good yields the following expression for real GDP per capita:

$$W_i = \frac{1}{H} \prod_{s=1}^{S+1} \left(\frac{w_i}{P_i^s} \right)^{\delta^{f,s}} \quad , \tag{2.15}$$

where

$$H = \prod_{s=1}^{S+1} \left(\delta^{f,s} \right)^{-\delta^{f,s}} \quad .$$

Thus, real income is a geometric average of the real wage expressed relative to the price of sector s composite, with the weight being each sector's weight in the final consumption good. Combining (2.9) with the expression for unit cost of the input bundle (V_i^s) yields the following expression for w_i/P_i^s for the tradable goods sectors:

$$\frac{w_i}{P_i^s} = \left(\frac{1}{A^s B^s} \right)^{\frac{1}{\beta^s}} \left(\frac{D_{ii}^s}{\lambda_i^s} \right)^{\frac{-\theta^s}{\beta^s}} \prod_{m=1}^{S+1} \left(\frac{P_i^m}{P_i^s} \right)^{\frac{-\xi^{s,m}(1-\beta^s)}{\beta^s}} \quad , \; s = 1, \ldots, S$$

For the non-traded sector, the analogous expression is given by

$$\frac{w_i}{P_i^N} = \left[\frac{A_i^N}{E} \prod_{s=1}^{S} \left(\frac{w_i}{P_i^s} \right)^{\phi^{N,s}(1-\gamma)} \right]^{\frac{1}{1-\phi^{N,N}(1-\gamma)}} .$$

Substituting the last two expressions in the expression for real wage gives us

$$W_i = \left(\delta^{f,N}\right)^{\delta^{f,N}} \left(\frac{A_i^N}{E} \right)^{\frac{\delta^{f,N}}{1-\phi^{N,N}(1-\gamma)}}$$
$$\prod_{s=1}^{S} \left(\delta^{f,s}\right)^{\delta^{f,s}} \left[\left(\frac{1}{A^s B^s} \right)^{\frac{1}{\beta^s}} \left(\frac{D_{ii}^s}{\lambda_i^s} \right)^{\frac{-\theta^s}{\beta^s}} \prod_{m=1}^{S+1} \left(\frac{P_i^m}{P_i^s} \right)^{\frac{-\xi^{s,m}(1-\beta^s)}{\beta^s}} \right]^{\frac{\delta^{f,N}\phi^{N,s}(1-\gamma)}{1-\phi^{N,N}(1-\gamma)}+\delta^{f,s}} . \quad (2.16)$$

Then the logarithm of the change in real GDP per capita is given by

$$\ln \widehat{W}_i = \sum_{s=1}^{S} \left(\underbrace{\frac{\delta^{f,N}\phi^{N,s}(1-\gamma)}{1-\phi^{N,N}(1-\gamma)}}_{\text{non-traded sector effect}} + \delta^{f,s} \right) \left[\underbrace{-\frac{\theta^s}{\beta^s} \ln \widehat{D}_{ii}^s}_{\text{trade effect}} - \underbrace{\frac{(1-\beta^s)}{\beta^s} \sum_{m=1}^{S+1} \xi^{s,m} \ln \left(\frac{\widehat{P}_i^m}{\widehat{P}_i^s} \right)}_{\text{inter-sector linkage effect}} \right] . \quad (2.17)$$

As discussed in Caliendo and Parro (2015), there are two main sources of gains from trade.[7] When there is reduction in trade barriers, trade increases, i.e., sectoral home expenditure shares, D_{ii}^s, will tend to decline ($\ln \widehat{D}_{ii}^s < 0$). This leads to an increase in welfare. The "trade effect"represents the standard gains driven by increased specialization and trade. A given decline in the sectoral home expenditures share, D_{ii}^s, leads to a larger increase in welfare if θ^s/β^s is high. A higher θ^s, which corresponds to a smaller trade elasticity for sector s, implies larger welfare gains essentially because goods are less substitutable. In addition, a lower β^s, or a higher intermediate input share in sector s leads to greater gains from trade. This owes to the "round-trip" effect discussed in Jones (2011).

The second source of gains stems from the change in relative prices of intermediates; we call it the "inter-sectoral linkages effect".[8] As trade barriers decline, the costs of imports

[7]There is also a third source of gains from trade - change in sectoral productivities, λ_i^s. However, as in Caliendo and Parro (2015) , we assume that sectoral productivities do not change.

[8]Caliendo and Parro (2015) call this the "sectoral linkages effect".

decline, which shows up as lower prices of sectoral intermediate goods. To the extent these prices decline relative to the price of the sector s output good that is being produced from these intermediates, there are gains from trade. A given relative price decline has a larger impact on welfare, the larger the share of the intermediate good in the output good's production process, i.e., the larger is $\xi^{s,m}$. In addition, the welfare gains are larger, the greater the intermediate input share in the sector s good $1-\beta^s$.

For both sources of gains, there is an additional effect coming from the weight of sector s goods in final consumption, which is captured by $\delta^{f,s}$. Finally, the non-traded final good has two partially offsetting effects. On the one hand, the presence of the non-traded good dampens the gains from trade coming from the inter-sector linkages. This negative effect of the non-traded sector on welfare is partially offset, because increased trade reduces the cost of the traded intermediate goods that are used to produce the non-traded good. The overall effect depends on the relative importance of intermediate composite of sector s in production of non-traded good, and the weight on the non-traded good in final consumption good. This effect is captured by the term $\frac{\delta^{f,N}\phi^{N,s}(1-\gamma)}{1-\phi^{N,N}(1-\gamma)}$.

It is worth noting that it cannot be immediately inferred from (2.17) that more heterogeneity automatically implies greater gains from trade. It depends on the details of the sectoral heterogeneity.

3 Calibration and Estimation Methodology

We now describe how we calibrate the model. The key parameters and variables to be calibrated are the θ^s, the trade costs, τ^s_{ij}, and the productivity parameters, λ^s_i.[9] Of these, the most important is calibrating the sector-specific parameter of θ^s that represents trade elasticities with respect to trade costs. We employ the simulated method of moments methodology introduced by Simonovska and Waugh (2014a) (hereafter, SW), for estimating these elasticities, θ^s, at the sectoral level. The estimation procedure employs micro-level price data, categorized into sectors, and sectoral trade flow data, with the latter captured by a 'gravity'

[9]We solve our model in 'levels'. Using a 'changes' methodology, as popularized by Dekle, Eaton, and Kortum (2008), would preclude the need to calibrate the productivity parameters and trade cost parameters, but that approach does not allow us to evaluate the fit of the benchmark model.

equation linking sectoral trade shares to source and destination fixed effects and to trade costs. We also describe our data sources, as well as the calibration of the other parameters. Finally, a number of our counterfactuals involve a one-sector model, and we describe how we calibrate and estimate that.

3.1 Sector-Level Trade Elasticity

To estimate the trade elasticity - $1/\theta^s$ - for each sector s, we use the simulated method of moments (SMM) estimation methodology developed by SW. A summary of the methodology is provided here; a detailed description is provided in Appendix B.

To obtain the equation to be estimated, according to (2.9), we can write:

$$\frac{D_{ij}^s}{D_{jj}^s} = \frac{(A^s B^s)^{-\frac{1}{\theta^s}} \left(\frac{V_j^s \tau_{ij}^s}{P_i^s}\right)^{-\frac{1}{\theta^s}} \lambda_j^s}{(A^s B^s)^{-\frac{1}{\theta^s}} \left(\frac{V_j^s \tau_{jj}^s}{P_j^s}\right)^{-\frac{1}{\theta^s}} \lambda_j^s} = \left(\frac{P_j^s \tau_{ij}^s}{P_i^s}\right)^{-\frac{1}{\theta^s}} .$$

The log version of this expression can be written as:

$$\log\left(\frac{D_{ij}^s}{D_{jj}^s}\right) = -\frac{1}{\theta^s}\log\left(\frac{P_j^s \tau_{ij}^s}{P_i^s}\right) , \tag{3.1}$$

Note that if we had only one sector, we would have $\frac{1}{\theta^s} = \theta^{EK}$ where θ^{EK} represents θ in EK. Similar to EK and SW, we construct the sectoral prices, inclusive of trade costs, using micro price data:

$$\log\left(\frac{P_j^s \tau_{ij}^s}{P_i^s}\right) = \max_x \left\{r_{ij}\left(x^s\right)\right\} - \sum_{x=1}^{H^s}\left[r_{ij}\left(x^s\right)\right]/H^s , \tag{3.2}$$

where $r_{ij}(x^s) = \log p_i^s(x^s) - \log p_j^s(x^s)$, $\max_x$ means the highest value across goods, and H^s is the number of goods in sector s of which prices are observed in the data.

For each sector s, we employ the SMM estimator as follows:

1. Estimate θ^s using trade and price data in (3.1) and (3.2) by the method of moments (MM) estimator as in EK. Call this θ_{EK}^s.

2. Estimate gravity equation given by (3.3) and (3.4) below. Since the data include zero-trade observations, we use poisson pseudo maximum likelihood (PPML) estimation

as advocated in Silva and Tenreyro (2006). The gravity equation estimates provide measures of sector-source-destination trade costs subject to the determination of θ^s.

3. For a given θ^s, say, θ^s_G, use source dummies in the gravity equation to estimate source marginal costs.

4. Use the trade cost and marginal cost estimates to compute the set of all possible destination prices and select the minimum price for each destination. These prices are the simulated prices. We allow for $50,000$ goods in each sector; we randomly draw goods prices from each of these pools.[10]

5. Using the simulated prices, calculate the model-implied trade shares, and call them as the simulated trade shares.

6. Using the simulated trade shares and simulated prices, estimate θ^s with the MM estimator. Call the estimate θ^s_S. Repeat this exercise $1,000$ times.

7. Find the θ^s_G that minimizes the weighted distance between θ^s_{EK} and the mean θ^s_S. The selected θ^s_G is the SMM estimate of θ^s. (See Appendix B for the exact moment conditions and objective function.) Call this θ^s_{SMM}.

Following Eaton, Kortum, and Kramarz (2011) and SW, we calculate standard errors using a bootstrap technique, taking into account both sampling error and simulation error. In particular, we proceed as follows:

1. Using the fitted values and residuals in the gravity equation of (3.3), resample residuals with replacement and generate a new set of data using the fitted values. This is very similar to Step 5 in SMM estimation, above.

2. For each resampling b, with the generated data set, estimate θ^s using MM estimator (as in EK) together with trade and price data in (3.1). Call this θ^s_b.

3. To account for simulation error, set a new seed to generate a new set of model-generated moments; i.e., follow Steps 2-7 for SMM estimation above to estimate $\theta^s_{b,SMM}$ for each bootstrap b.

[10] In SW, the total number of goods in the one-sector model is 100,000.

4. Repeat this exercise 25 times and compute the estimated standard error of the estimate of θ^s_{SMM} as follows:

$$S.E.\left(\theta^s_{SMM}\right) = \left[\frac{1}{25}\sum_{b=1}^{25}\left(\theta^s_{b,SMM} - \theta^s_{SMM}\right)'\left(\theta^s_{b,SMM} - \theta^s_{SMM}\right)\right]^{\frac{1}{2}}$$

where $\theta^s_{b,SMM}$ is a vector with the size of (25×1).

3.2 Sector-Level Bilateral Trade Costs: Gravity Equation Estimation

Given estimates of the trade elasticities, $1/\theta^s$, we can compute bilateral trade costs for every sector by estimating (3.3) below. A gravity-type expression for trade at the sector-level can be obtained using (2.9):

$$\frac{D^s_{ij}}{D^s_{ii}} = \left(\frac{V^s_j \tau^s_{ij}}{V^s_i}\right)^{-\frac{1}{\theta^s}} \frac{\lambda^s_j}{\lambda^s_i}$$

Let $\Omega^s_i = \left(V^s_i\right)^{-\frac{1}{\theta^s}} \lambda^s_i$ and $T^s_i = \ln\left(\Omega^s_i\right)$. Then

$$\ln\left(\frac{D^s_{ij}}{D^s_{ii}}\right) = T^s_j - T^s_i - \frac{1}{\theta^s}\ln\left(\tau^s_{ij}\right) \tag{3.3}$$

We estimate (3.3), where, as in Waugh (2010), we specify trade costs as follows:

$$\ln \tau^s_{ij} = \underbrace{dist_I}_{\text{distance}} + \underbrace{brdr}_{\text{border}} + \underbrace{lang}_{\text{language}} + \underbrace{tblk_G}_{\text{trade block}} + \underbrace{src^s_i}_{\text{source effect}} + \varepsilon^s_{ij} \quad , \tag{3.4}$$

where $dist_I$ $(I = 1, \ldots, 6)$ is the effect of distance between i and j lying in the Ith interval, $brdr$ is the effect of i and j sharing a border, $lang$ is the effect of i and j sharing a language, $tblk_G$ $(G = 1, 2)$ is the effect of i and j belonging to a free trade area G, and src_i $(i = 1, \ldots, n)$ is a source effect. The error term ε^s_{ij} captures trade barriers due to all other factors, and is assumed to be orthogonal to the regressors. The errors are assumed to be normally distributed with mean zero and variance, σ_ε. The six distance intervals (in miles) are: $[0, 375)$; $[375, 750)$; $[750, 1500)$; $[1500, 3000)$; $[3000, 6000)$ and $[6000, \text{maximum}]$. The two free trade areas are the European Union (EU) and the North-American Free Trade Agreement

(NAFTA). T_i^s is captured as the coefficient on source-country dummies for each sector s.

3.3 Sector-Level Technology Parameters

To infer the technology parameters of the traded goods sectors, λ_i^s, we use the full information from the gravity equation, as done in Waugh (2010). The technology parameter of the non-traded goods sector, A_i^N, is chosen to match the GDP per capita in the data. The procedure is outlined below:

Step 1 - Estimate trade costs, τ_{ij}^s, and country dummies, T_i^s, using the gravity equation - (3.3) and (3.4).

Step 2 - Since $\Omega_i^s = (V_i^s)^{-\frac{1}{\theta^s}} \lambda_i^s$ and $T_i^s = \ln(\Omega_i^s)$, compute price of sector s composite good as

$$P_i^s = A^s B^s \left(\sum_{j=1}^{N} e^{T_j^s} \tau_{ij}^{s\,-\frac{1}{\theta^s}} \right)^{-\theta^s} . \tag{3.5}$$

Step 3 - Start with a guess of A_i^N. Taking L_i and D_{ij}^s from the data, solve for price of non-traded sector's composite good, per capita expenditures, wages, and labor allocations using (2.5), (2.11), (2.12), (2.13), and (2.14).

Step 4 - Then update A_i^N using the expression for GDP per capita (data comes from Penn World Tables (PWT))

$$W_i = \frac{1}{H} \prod_{s=1}^{S+1} \left(\frac{w_i}{P_i^s} \right)^{\delta^{f,s}} ,$$

where

$$H = \prod_{s=1}^{S+1} \left(\delta^{f,s} \right)^{-\delta^{f,s}} .$$

If distance between starting guess and updated values of A_i^N is smaller then a threshold then move to the next step, else replace the guess in step 3 by the updated values and repeat steps 3 and 4.

Step 5 - Lastly, the productivity parameter for sector s in country i, λ_i^s, is obtained using the relationship

$$\Omega_i^s = (V_i^s)^{-\frac{1}{\theta^s}} \lambda_i^s = e^{T_i^s} , \tag{3.6}$$

where V_i^s is the factor cost, given by (2.2).

3.4 Data for Estimating Sectoral Trade Elasticities, Trade Costs, and Productivities

The data on prices of goods, needed for the estimation of sectoral θ's, come from Eurostat surveys of retail prices in the capital cities of EU countries for the year 1990. The data set has been compiled by Crucini, Telmer, and Zachariadis (2005) and used by Giri (2012), Inanc and Zachariadis (2012), and Yorukoglu (2000).[11] We use price data for 12 countries included in the surveys - Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain and United Kingdom. The goods maintain a high degree of comparability across locations; typical examples of item descriptions are "500 grams of long-grained rice in carton", or "racing bicycle selected brand". The level of detail is for some cases at the level of the same brand sampled across locations. This enables exact comparisons across space at a given point in time. The retail price of a good in a given country is the average of surveyed prices across different sales points within the capital city of that country. Furthermore, the effect of different value added tax (VAT) rates across countries has been removed from the retail prices. The price data cover 1896 goods for the year 1990; we use 1410 of these goods prices. Each good is then assigned to one of our 19 ISIC sectors. For example, long-grained rice is assigned to sector 311 (Food products), and racing bicycle to sector 384 (Transport equipment). The sample size of prices in each sector (H^s) is given in Table 4.

In our framework, as is standard in EK-type multi-country models, we assume that within country trade and distribution costs are zero. To square this assumption with the reality of distribution costs, mark-ups, and other costs that make retail prices different from at-the-importing-dock prices, we assume, as do SW, that such costs have the same proportional effect on at-the-importing-dock prices across all goods.[12] Under this assumption, the solution of the model is identical to the one in which within country costs are zero.

Data on output and bilateral trade by sectors for 1990 come from the Trade, Production and Protection database of the World Bank. They provide a broad set of data covering measures of trade, production and protection for 21 OECD countries and 28 manufacturing

[11] The data can be downloaded from http://www.aeaweb.org/articles.php?doi=10.1257/0002828054201332.
[12] An alternative approach is to explicitly model such costs, as in Giri (2012)

sectors corresponding to the 3-digit level International Standard Industrial Classification (ISIC), Revision 2.[13] Out of the 28 manufacturing sectors, we use data for 21 sectors, because, for the other sectors, there are many missing observations on trade volumes. For the same reason, we also combine sectors 313 (Beverages) and 314 (Tobacco) into one single sector and sectors 341 (Paper and paper products) and 342 (Printing and Publishing) into another single sector. The description of the 19 sectors is provided in the appendix in Table 6.[14] The data on trade barriers - distance, border and language - come from Centre D'Etudes Prospectives Et D'Informations Internationales[15].

To compute the trade shares for a sector s - share of country j in country i's total expenditure on sector s goods - total exports of a country are subtracted from its gross output. This gives each country's home purchases for a sector (X_{ii}^s). Adding home purchases and total imports of a country gives the country's total expenditure on sector s goods (X_i^s). Normalizing home purchases and imports of an importing country from its trading partners by the importer's total expenditure creates the expenditure shares - D_{ij}^s - that are used in the gravity equation estimation.

3.5 Calibration of Other Parameters

In this section, we explain how the other parameters of the model are calibrated. β^s is computed as the, average across countries, share of value added in gross output of a sector. The data on value added and gross output by sector come from the World Bank Trade, Production and Protection database. γ is computed as the, average across countries, share of value added in the gross output of non-traded goods' sector. The non-traded sector includes everything except manufacturing. To compute γ we use data from the OECD STAN Structural Analysis database (STAN Industry, ISIC Rev. 2 Vol 1998 release 01). We find γ to be 0.61.

[13]The countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom, and United States.

[14]Sectors dropped due to missing data on trade volumes are Industrial chemicals, Petroleum refineries, Miscellaneous petroleum and coal products, Non-ferrous metals, Machinery, except electrical, Professional and scientific equipment, and Other manufactured products.

[15]http://www.cepii.fr

$\xi^{s,m}$, which represents the share of sector $m = 1, \ldots, S+1$ in the expenditure of traded goods sectors $s = 1, \ldots, S$ on intermediate inputs is computed using the input-output table of the United States for the year 1990. The same data and computations are also used to get $\phi^{N,m}$ - the share of sector $m = 1, \ldots, S+1$ in the expenditure of non-traded goods sector on intermediate inputs. Lastly, we use the same data to compute $\delta^{f,s}$ as the share of sector $s = 1, \ldots, S+1$ in final domestic expenditure.

η^s is the elasticity of substitution between goods of a sector. Anderson and Wincoop (2004) find that elasticity of demand for imports at sector level is between 5 and 10. However, as in EK, this parameter does not have any implications for the results of the model. We choose $\eta^s = 2$ for all sectors. This is the highest value that ensures that the Gamma function determining A^s is well defined for all sectors.

Table 1 summarizes the calibration of all the parameters of the model and Table 2 provides more detail on the sector level value added shares in production, and shares in final domestic expenditure.

Table 1: Summary of Parameters

Parameter	Description	Value	Source
τ_{ij}^s	trade cost		estimated (section 3.2)
$1/\theta^s$	trade elasticity of sector	Table 4	estimated (section 3.1)
λ_i^s	Frechet parameter for traded goods sectors		computed (section 3.3)
A_i^N	productivity in non-traded goods sector		GDP per capita (PWT) (section 3.3)
γ	value added share in gross output for non-traded good sector	0.61	OECD STAN data
β^s	value added share in gross output for traded goods sectors	Table 2	World Bank data
$\xi s, m$	expenditure on intermediates by traded goods sectors	Table 7	US IO table 1990
$\phi N, m$	expenditure on intermediates by non-traded goods sector	Table 7	US IO table 1990
$\delta^{f,s}$	share of sector in final domestic expenditure	Table 2	US IO table 1990
η^s	elasticity of substitution within traded goods sectors	2	EK

Table 2: β^s and $\delta^{f,s}$

ISIC Code	β^s	$\delta^{f,s}$
311	0.2603	0.0232
313,314	0.4911	0.0232
321	0.3878	0.0049
322	0.4269	0.0049
323	0.3296	0.0049
324	0.3925	0.0049
331	0.3565	0.0036
332	0.4150	0.0036

Table 2: (continued)

ISIC Code	β^s	$\delta^{f,s}$
341,342	0.4285	0.0139
352	0.4421	0.0135
355	0.4380	0.0014
356	0.4085	0.0014
361	0.5829	0.0003
362	0.5003	0.0003
369	0.4512	0.0003
371	0.3391	0.0000
381	0.4180	0.0003
383	0.4176	0.0171
384	0.3469	0.0493
400	0.6090	0.8288

3.6 Calibration of One-sector Model

One set of counterfactual exercises that we perform involve an aggregated version of our model that collapses the 19 traded goods sectors of our benchmark model into a single traded good sector. There continues to be a non-traded good sector.[16] We first estimate the single $1/\theta$ for this model, and then we estimate the trade costs and technology parameters following the same procedure as in our benchmark model, except we now use aggregated trade data and we view all the micro-prices as coming from a single traded sector. (We present the $1/\theta$ estimate in the next section.) With this model, we examine the gains from trade, and compare it to the benchmark model. Table 3 shows the key parameters in this version of the model.

Table 3: Parameters for One Sector Model

β	δ	γ
0.37	0.17	0.61

Note: $\delta = \sum_1^S \delta^{f,s} = 1 - \delta^{f,N}$.
Note: β is computed as average across countries of the ratio of sum of value added of all traded goods sectors to the sum of gross output of all traded goods sectors.

[16]We continue to have an input-output structure, but now it is just a 2 x 2 matrix.

4 Results

We first present our estimated trade elasticities and then turn to the welfare gains from our benchmark model, as well as from our two sets of exercises.

4.1 Estimated Trade Elasticities

Table 4 presents the results of the estimation of trade elasticites - $1/\theta^s$. The column labeled "SMM-PPML" shows the estimates coming from our application of the SW SMM methodology with PPML estimation of the gravity equation.[17] Standard errors for each estimate are in parentheses. For comparison, we also estimate the sectoral elasticities with the original Eaton and Kortum (EK) methodology. The column labeled "EK" provides the estimates resulting from the EK estimator. The last column shows the number of goods in each sector (after mapping the individual goods into the 3 digit ISIC sector categories).

Our sectoral trade elasticity estimates range from 2.97 (ISIC 341 and 342, Paper and products; printing and publishing) to 8.94 (ISIC 371, Iron and steel); and the median is 4.38 (ISIC 355, Rubber products). Using the EK method, the trade elasticity estimates range from 4.26 to 35.55 with a median of 10.29. As Table 4 shows, for each sector, our SMM estimate of the trade elasticity is smaller than the estimate obtained by the EK methodology.

Hence, our sectoral SMM estimates mirror the results obtained by SW in their one-sector framework. As SW found, we also find that the "bias" is larger the smaller the sample size. For example, ISIC 352, Other chemicals, has a sample size of only 4, while ISIC 311, Food products, has a sample size of 343. Our SMM estimate for Other chemicals is 3.75, as opposed to 11.93 with the EK methodology, while our estimate for Food products is 3.57, as opposed to 4.28 with the EK methodology.

Caliendo and Parro (2015) also estimate structurally consistent estimates of sectoral trade elasticities using a triple-difference approach. However, they utilize sector-level data – sector-level tariff rates – to estimate their trade elasticities. Our estimates overall show a smaller range than the manufacturing sectors estimates in Caliendo and Parro (2015),

[17] We also estimated the elasticity by OLS. The estimates are very similar to the PPML estimates. This suggests that the issue of zeros in trade-flow data is not significant with our data.

although the median estimates are similar. The highest estimated elasticity in Caliendo and Parro (2015) is 65 (99 percent sample; petroleum), and the lowest is 0.39 (99 percent sample, other transport). Note that their lowest elasticity, as well as the lowest estimated elasticity in Ossa (2015), 0.54, are both considerably smaller than our lowest estimated elasticity, 2.97. This will be important for our interpretation of our welfare results vis-a-vis these other papers later.

It is worth pointing that using the EK methodology it would be difficult to get such low estimates, even when the sample size is large. The reason is the following. From (3.1) and (3.2), we can see that the estimate for $1/\theta^s$ is essentially the mean across country-pairs of the ratio of the log bilateral trade share and the maximum log bilateral price difference minus the average log bilateral price difference. It turns out that the average log bilateral price difference is very close to 0 in the data for most country-pair-sector combinations. Hence, given the log bilateral trade share in the data, the maximum log bilateral price difference is what determines the estimate for $1/\theta^s$. Consider the Food products sector; as Table 4 shows, the EK estimate of $1/\theta^s$ for this sector is 4.28. The maximum log price difference is 1.2, which translates to a factor of 3.3 difference in prices. In other words, if the lowest price is 1, then the highest price is 3.3. Consider the following question: given the log bilateral trade share in the data, what would the maximum price difference need to be if the EK estimate of $1/\theta^s$ was 1.5? The maximum log price difference would be 3.4, which translate to a factor 30.4 difference in prices. In other words, if the lowest price is 1, the highest price would be 30.4. This seems unlikely for our sample of countries.

Our SW estimates of $1/\theta^s$ are lower than the EK estimates, but our point from the preceding paragraph is that using a model-consistent price approach to estimating $1/\theta^s$ will not yield low elasticities unless the maximum price differences are – we argue – counterfactually large.

Table 4: Estimates of Trade Elasticities by Sector ($1/\theta^s$)

ISIC Code	Sector Description	SMM-PPML	EK	Sample Size of Prices
311	Food products	3.57 (0.31)	4.28	343
313,314	Beverages and Tobacco	3.57 (0.22)	5.36	93
321	Textiles	3.27 (0.2)	5.21	36
322	Wearing apparel, except footwear	4.41 (0.33)	5.17	143
323	Leather products	5.28 (0.3)	8.14	20

Table 4: (continued)

ISIC Code	Sector Description	SMM-PPML	EK	Sample Size of Prices
324	Footwear, except rubber or plast	4.77 (0.49)	10.29	20
331	Wood products, except furniture	4.17 (1.26)	15.45	8
332	Furniture, except metal	4.47 (0.31)	15.37	5
341,342	Paper and products and printing and publishing	2.97 (0.18)	6.57	14
352	Other chemicals	3.75 (0.22)	11.93	4
355	Rubber products	4.38 (0.54)	8.02	14
356	Plastic products	3.87 (1.41)	16.00	8
361	Pottery, china, earthenware	5.94 (0.59)	19.79	14
362	Glass and products	5.61 (0.67)	19.08	6
369	Other non-metallic mineral products	3.87 (0.47)	14.10	7
371	Iron and steel	8.94 (1.55)	35.55	16
381	Fabricated metal products	5.07 (1.42)	18.50	11
383	Machinery, electric	3.27 (0.21)	4.26	416
384	Transport equipment	4.47 (0.8)	6.50	232
	Minimum	2.97	4.26	4.00
	Maximum	8.94	35.55	416.00
	Average	4.51	12.08	74.21
	Median	4.38	10.29	14.00

4.1.1 Estimated Trade Elasticity for One-Sector Model

Our estimate of $1/\theta = 2.37$. While the estimate is close to what SW obtain with EIU price data, 2.82, the estimate is lower than even the minimum of our sectoral elasticity estimates. This estimate can be understood via the following logic. First, the estimate using the EK methodology is 2.97 – which is also lower than the minimum of the sectoral estimates using the EK methodology. However, this is straightforward to understand, because the sample size is larger; we are using the full sample of 1410 goods prices. SW showed that the upward bias in the EK estimator is larger with smaller samples; thus, when a large sample is used, typically smaller estimates of $1/\theta$ will arise. Hence, a smaller aggregate estimate than the minimum sectoral estimate should not be surprising. Second, we know that the SW estimate will be less than the EK estimate, i.e., $1/\theta_{sw} \leq 1/\theta_{ek}$. We will see later that this low estimate plays a key role in our assessment of the gains from trade in our benchmark model vs. the one-sector model.

4.2 Welfare Gains of Benchmark Multi-Sector Model

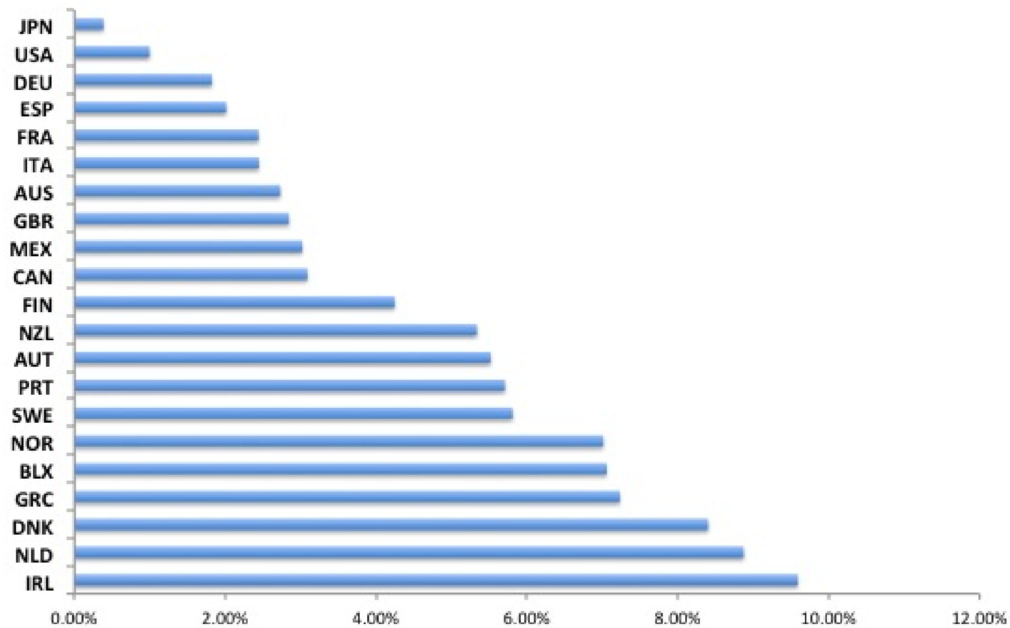
In order to assess the welfare gains from trade, we use real GDP per capita as the measure of welfare. We use our estimates of $1/\theta^s$, and the values of λ_i^s, A_i^N, and τ_{ij}^s calibrated from the methodology described above, and solve for baseline equilibrium wages, per capita expenditures, labor allocations, prices of sectoral intermediate composites, and trade shares. Using the same λ_i^s and A_i^N we solve for an autarky equilibrium by setting trade costs to 100 times their baseline level. Then, using real GDP per capita, $W_i = w_i/P_i$, as the measure of welfare, we compute the change in welfare as $\ln\left(W_i^a/W_i^b\right) \times 100$, where W_i^a denotes the autarky value and W_i^b denotes the baseline value. P_i is the price of the final consumption good, given by (2.7).

We now study the gains from trade in our benchmark model. We compute the gains from trade in the same way as done recently in ACR, Levchenko and Zhang (2014), Costinot and Rodriguez-Clare (2014), Ossa (2015), and other papers, with one slight difference. Rather than computing the welfare change in going from the actual 1990 data to autarky, we compute the welfare change from the model's representation of 1990 to autarky. We do this so that we can assess the fit of the benchmark model.

Hereafter, we will represent the welfare change as the gains in going from autarky to the baseline (model-implied) trade share. The gains from trade are given in column (1) in Table 5 and in Figure 1 below for each country. The welfare gain ranges from 0.38% for Japan to and 9.59% for Netherlands with a median (mean) gain of 4.25% (4.60%). The gains for small countries are about an order of magnitude larger than for the largest countries. These gains are of the same magnitude, roughly, as those found in EK, for example.

Figure 2 illustrates the contribution of each sector to the welfare gain of each country. In most countries, only a few sectors account for most of the welfare gains from trade. For example, in Japan, sectors 383 (machinery, electric) and 384 (transport equipment) account for almost 90% of the gains. These two sectors, along with sectors 341 (paper products and publishing) and 311 (food products) account for the majority of the gains from trade in most countries. By and large, these are the sectors which are experiencing the highest trade flows, as captured by $-\hat{D}_{ii}$. That said, the figure shows there is considerable heterogeneity across

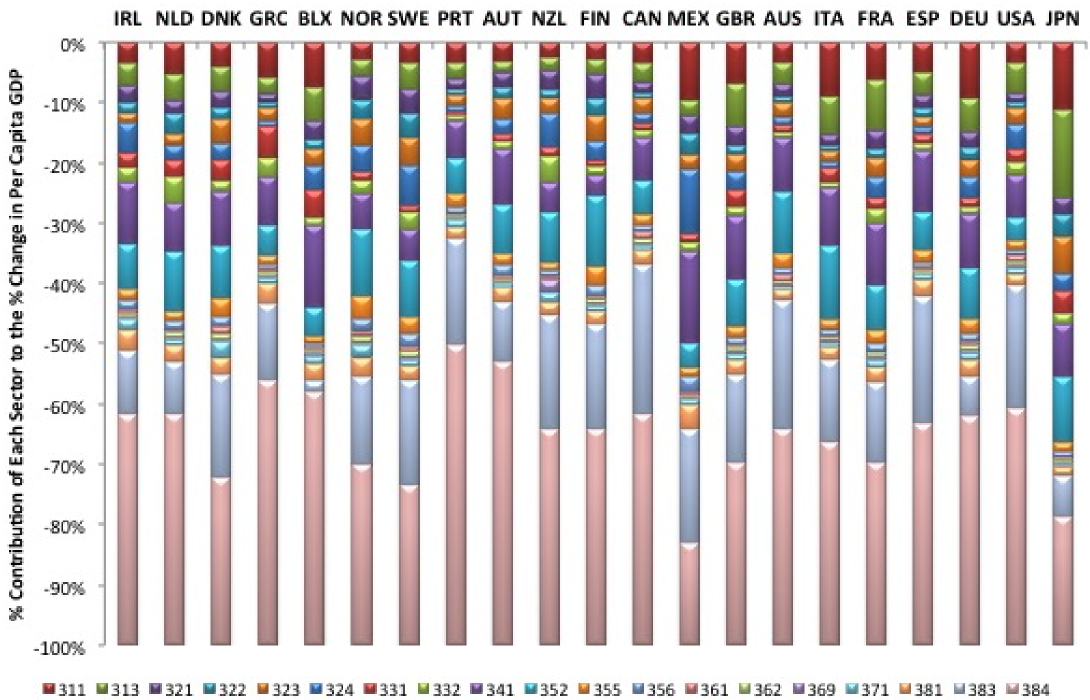
Figure 1: Welfare Gains from Trade (relative to Autarky)



countries in the importance of particular sectors to the gains from trade. Thus, comparative advantage at the sector-level is an important factor determining the welfare gains from trade. Our results here are consistent with Ossa (2015), who finds with more disaggregated data that the top 10 percent of the his industries account for 90 percent of the gains.

We also decompose our results into a the direct trade owing to changes in home expenditure shares D_{ii} and an intersectoral linkage effect owing to changes in intersectoral prices, as discussed above. From equation (2.17), the direct trade effect is captured by the first term in brackets, and the intersectoral linkage effect is captured by the second term. Figure 3 shows the results. For every country, the direct trade effect in going from autarky to the baseline equilibrium is positive, while the intersectoral price effect is negative. Also, the absolute magnitude of the direct effect is larger; hence, the overall effect is positive. Why does the intersectoral price effect work in the opposite direction from the direct trade effect? as noted above, the direct trade effect is positive as domestic sectoral expenditures shares decrease. The intersectoral linkage effect is driven by changes in the prices of the sectoral inputs relative to the output price of a sectoral good. Owing to the reduction of trade costs, the traded sectoral prices fall, some more than others. However, the non-traded sectoral

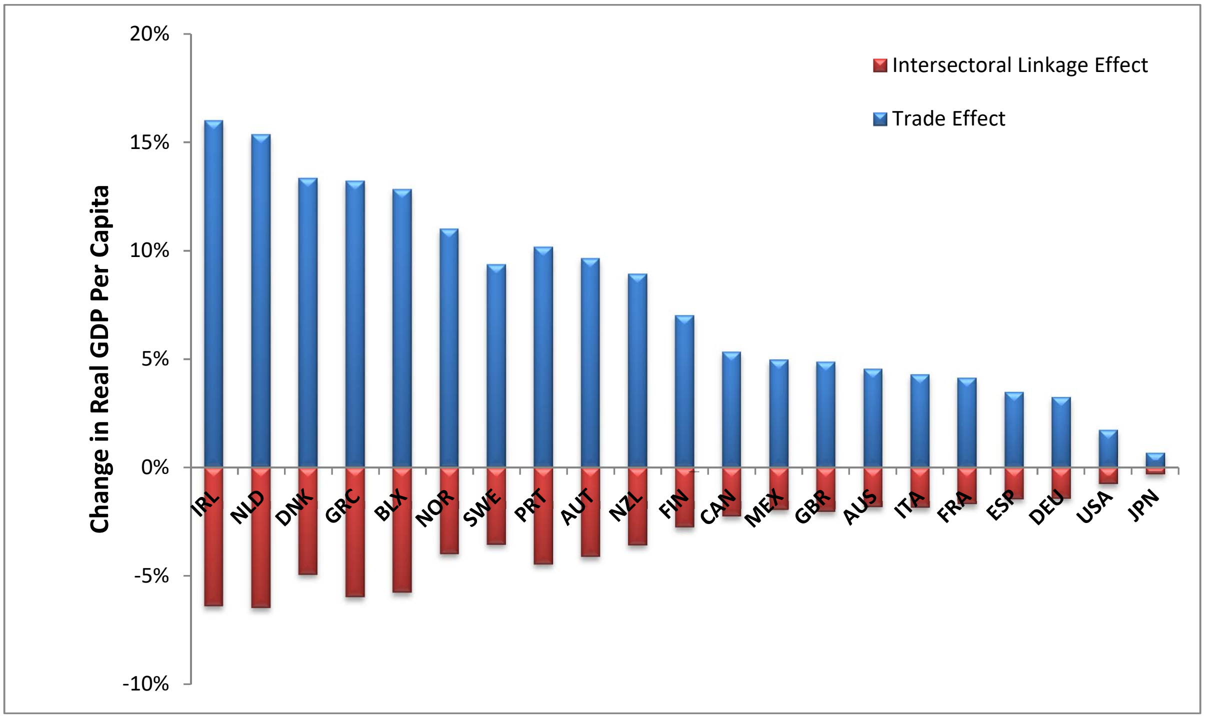
Figure 2: Contribution of Sectors to Welfare Gains - Benchmark Case (sector-specific θ's)



good is different for two reasons. First, the importance of the wage (the value-added share γ) in the non-traded good is considerably higher than in traded goods, and second, the non-traded good is the dominant input in traded goods (as captured by a large $\xi^{s,N}$ coefficient). Because the real wage increases in going from autarky to our baseline equilibrium, nominal wages must rise by more than the appropriate geometric-weighted average of prices. Hence, the non-traded good price will rise by more than the traded goods prices, which implies that, on average, input prices relative to the sectoral output price rise when the economy moves closer to free trade. Thus, the inter-sectoral linkage effect will be welfare reducing, all else equal.

To summarize our two main results in this section, we find first that only a few sectors account for most of the gains from trade, and that these sectors tend to vary across the countries. Second, owing to the large share of wages in non-traded goods prices, and the large share of non-traded goods as an intermediate input into traded goods, the intersectoral price welfare effect partially offsets the trade linkages welfare effect.

Figure 3: Role of Intersectoral Linkages

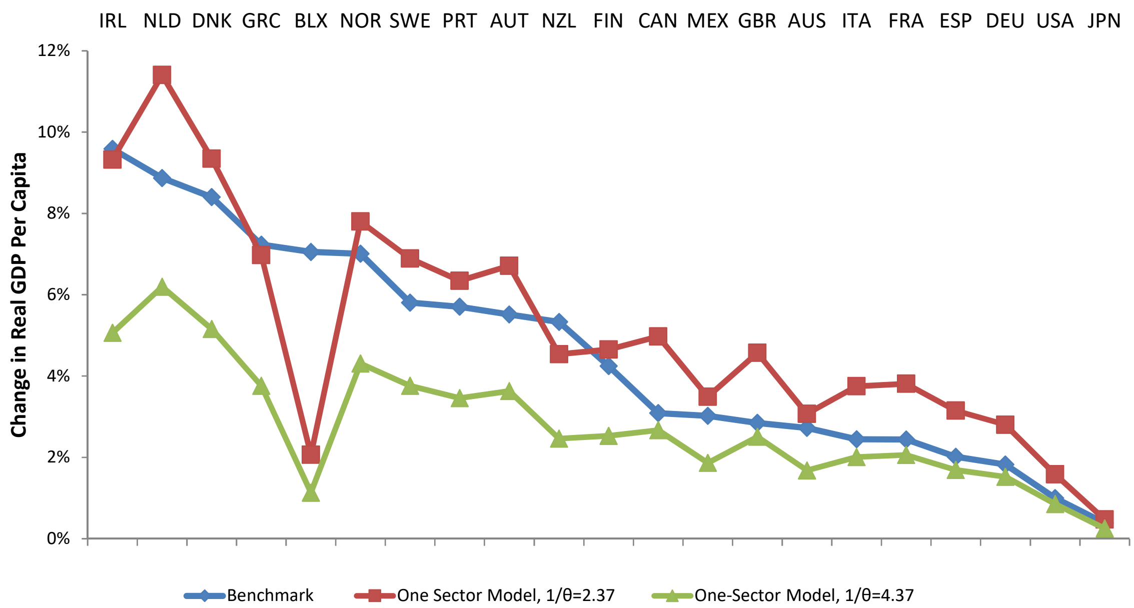


4.3 Role of Sectoral Heterogeneity

Our framework has five sources of sectoral heterogeneity – trade elasticities, input-output structure, value-added shares, trade costs, and productivities – and they all influence the gains from trade, as captured by (2.17). To assess the importance of this heterogeneity in the gains from trade calculations, we conduct two sets of counterfactuals. The first set of counterfactuals compares our benchmark model to a calibrated one-sector model in which each of the five sources of sectoral heterogeneity is replaced with a single, aggregate value (covering all the tradable sectors). This provides a comprehensive look at the importance of sectoral heterogeneity. The second set of counterfactuals addresses the importance of individual sources of heterogeneity: the trade elasticities, value-added shares, and input-output structure, one at a time. We start from the benchmark model, and then replace the sector-level parameter vector with a single parameter common to all sectors. For example, to assess the importance of heterogeneity in the sectoral trade elasticities $1/\theta^s$, we replace the sector level $1/\theta^s$ with a single aggregate θ. All other sources of heterogeneity are unchanged. For both sets of counterfactuals, to maintain consistency with the sector-level trade and output data, the trade costs and productivities are re-calibrated following the steps discussed in sections 3.3 and 3.4. We then raise trade costs to autarky levels and compute the gains from trade.[18]

4.3.1 Benchmark Model vs. One-Sector Model

Figure 4: Benchmark Model vs. One-Sector Model



This section presents the first set of counterfactuals. We calibrate and estimate a one (tradable) sector model, i.e., each of the five sources of sectoral heterogeneity is replaced by a single parameter. The red line in Figure 4 shows the gains from trade from the one-sector model. The gains from the benchmark model are plotted in blue. The countries in this and ensuing figures are ordered left to right in descending order of gains in the benchmark model. It can be seen that with the exception of Belgium-Luxembourg and New Zealand, the gains are typically slightly larger with the one-sector model. This is one of the main results of the paper: when the benchmark model, with its model-consistent estimates of sectoral

[18]Note that this exercise will alter both the baseline level of welfare and the autarky level of welfare. Because of this, we focus on the difference between the baseline and autarky levels of welfare.

trade elasticities and its five sources of sectoral heterogeneity, is compared to the one-sector model, with its model-consistent estimate of the aggregate trade elasticity, and no sources of sectoral heterogeneity, the benchmark model does not yield substantially greater gains from trade. In fact, for most countries it produces lower gains from trade.

How can this surprising result be explained and how is it consistent with the results of Costinot and Rodriguez-Clare (CRC, 2014) and Ossa (2015), who find that their multi-sector models deliver much larger gains than their one-sector models? Even though there are five sources of heterogeneity, our interpretation is that just one source, the trade elasticities, plays a key role. A central factor is the elasticities of trade in the multi-sector benchmark model relative to the elasticity of trade in the one-sector model. Comparing the elasticities in our paper to those in CRC and Ossa, our sectoral trade elasticity estimates are somewhat higher, and our one-sector elasticity is lower. These elasticities push the gains from trade in our multi-sector model relatively lower and the gains from trade in our one-sector model relatively higher. Regarding the multi-sector model, in Ossa's multi-sector model, a number of elasticities are close to and even less than 1. All else equal, an elasticity of 1 delivers 10 times the gains from trade as an elasticity of 10. Put differently, the gains in a world with two sectors with elasticities of 1 and 10 will be several times larger than the gains in a world with two sectors with elasticities both equal to 5. Indeed, Ossa shows that just 10 percent of the industries account for 90 percent of the gains.[19] Regarding the one-sector model, we conduct an exercise in which we replace our estimated one-sector elasticity, 2.37 with the median of our sectoral elasticities, 4.38, and we then compute the gains from trade in our one-sector model. This exercise is similar to that in CRC and in Ossa. The green line in Figure 4 provides the results. The figure shows that the gains from the benchmark model are about twice as large as in the one-sector model. This result is qualitatively similar to that in CRC and Ossa.

What about the other four sources of sectoral heterogeneity? Does heterogeneity in these sources imply greater gains from trade? To address this question, we adjust both the benchmark and one-sector models so that they have the same trade elasticity (we use the

[19] In private correspondence, Ossa indicated that these industries were largely the industries with the lowest elasticities. We thank Ossa for this correspondence.

median $1/\theta$ from the benchmark model). We then compute the gains from trade in each model.[20] The results are shown in columns (3) and (9), respectively, in Table 5. The welfare gains for the benchmark model, with its additional heterogeneity in value-added shares, input-output structure, trade costs, and productivities, are roughly fifty percent higher than in the one-sector model. Hence, but for the trade elasticity estimates, the increase in sectoral heterogeneity produces greater welfare gains. Similar results are shown for different values of $1/\theta$ in columns (2) and (8), and also in columns (4) and (7).[21]

We draw three conclusions from the first set of counterfactuals. First, and most important, when we use the elasticities that we estimate, i.e., the model-consistent elasticities, we find that the benchmark multi-sector model delivers slightly lower gains from trade than the one-sector model. In other words, more sectoral heterogeneity does not deliver greater gains from trade. Second, when we modify our exercise to make it similar to what CRC, as well as Ossa, do, then, we get qualitatively similar results to them – the benchmark model yields higher gains from trade than the one-sector model. Third, if we control for the trade elasticities, i.e., focus only on the other sources of sectoral heterogeneity, we find that, collectively, they do imply greater gains from trade compared to a one-sector model.

4.3.2 Importance of Individual Sources of Sectoral Heterogeneity

We now turn to the second set of counterfactuals, which involve individual sources of sectoral heterogeneity. We start by examining the role of heterogeneity in the elasticity of trade $1/\theta^s$ – does sectoral heterogeneity in $1/\theta^s$ alone delivers additional gains from trade? We compare our benchmark model to a version of that model in which the sectoral elasticities are replaced by a single elasticity common to all sectors. Note that this exercise differs from our exercise in the previous sub-section in which we compared our benchmark model to a one-sector model. The key issue in this exercise is the value of the single elasticity. We use three values of the elasticity: our estimate from the one-sector model, $1/\theta = 2.37$; the median of our

[20] This exercise is similar to that in Levchenko and Zhang (2014).

[21] We conducted one more set of counterfactuals. We compare the one-sector model with a simplified version of the one-sector model in which the 2 x 2 input-output structure is replaced by a 2 x 2 diagonal matrix. Comparing columns (7) to (12), (8) to (11), and (9) to (10), all show that the diagonal matrix delivers slightly greater gains from trade. This indicates that not including for linkages between the tradable and non-tradable sector leads to slightly larger GFT.

sectoral theta estimates, $1/\theta = 4.38$; and the main estimate from EK, $1/\theta = 8.28$. Figure 5 illustrates the welfare gains from the benchmark model compared to the benchmark model with the sectoral elasticities replaced by each of these single elasticities.

The blue and green lines in the figure show that when the sector-specific $1/\theta$'s are replaced by the median of the sector-specific $1/\theta$'s, the welfare gains are about the same or slightly lower, relative to the benchmark model, across all the countries. In other words, in this comparison, sectoral heterogeneity in $1/\theta^s$ provides about the same, or slightly greater, welfare gains. We can see why the effect is so small by focusing on the first term in brackets from (2.17), i.e., $-\frac{\theta^s}{\beta^s} ln\widehat{D}_{ii}^s$. This is the key term in the 'trade effect' discussed above. Because we re-calibrate the model for each exercise so that sectoral trade flows are consistent with those in the data, the sectoral home expenditure share changes little across exercises. Hence, heterogeneity in $1/\theta^s$ will lead to larger gains from trade to the extent that $1/\theta^s$ is small when β^s is small and when $ln\widehat{D}_{ii}^s$ is large. It turns out that the two sectors in which $ln\widehat{D}_{ii}^s$ is large are ISIC 383 and 384 (electric machinery and transport equipment), and both sectors have a $1/\theta^s$ that is close to the median value. Moreover, their value-added share, β^s, are close to the average value of β^s. Hence, for these two sectors, which are the major sources of the gains from trade for most of the countries, replacing the sector-specific $1/\theta^s$ with the median $1/\theta^s$ changes the gains from trade by very little. This is the main reason why the gains from trade in this case is so similar to the gains from trade (GFT) in the benchmark model.

On the other hand, if we replace the sector-specific $1/\theta$'s with the actual estimate of $1/\theta$ from our one-sector model, 2.37, we can see that the GFT with the lower $1/\theta$ are close to twice as large as in our benchmark model. The importance of the value of $1/\theta$ that is used in this counterfactual can also be seen when we compute the welfare gains from using the estimated $1/\theta$ from EK: 8.28. In this case, the gains from trade are only about one-half as large as in the benchmark model. Hence, it is clear that the value of $1/\theta$ that is used in the comparison matters. But, our main conclusion is from the counterfactual with the median $1/\theta$ – in this case, including sector-specific $1/\theta$'s leads to little change in the gains from trade.

We now study the effects of heterogeneity in sector-level value-added shares of gross

Figure 5: Role of Sectoral Heterogeneity in Trade Elasticity ($1/\theta$) in Benchmark Model

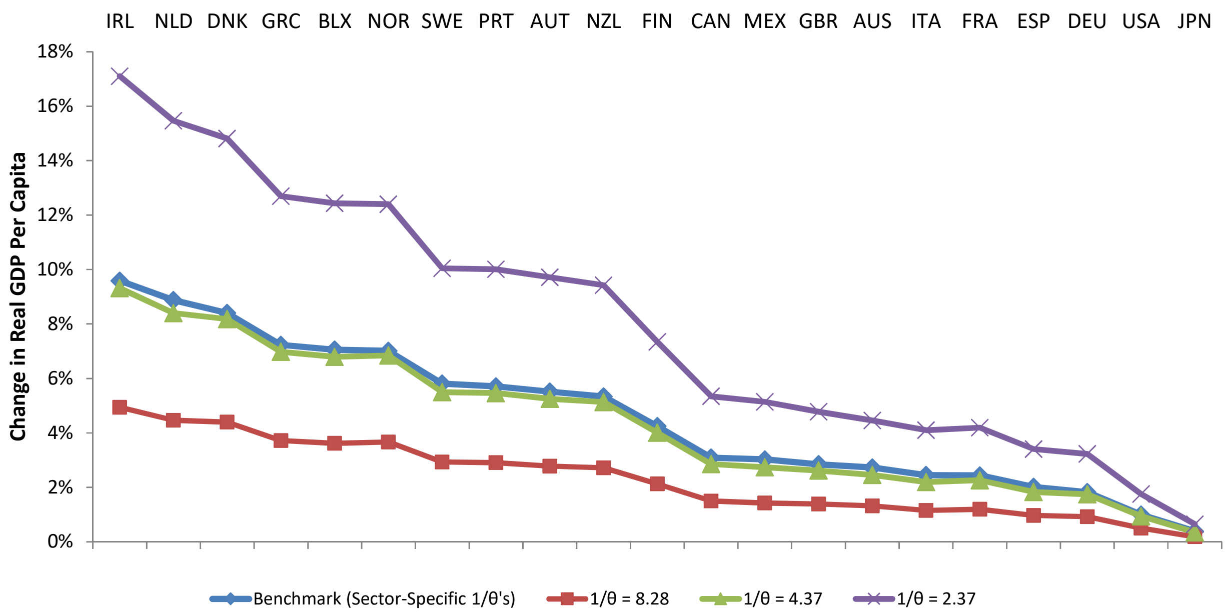
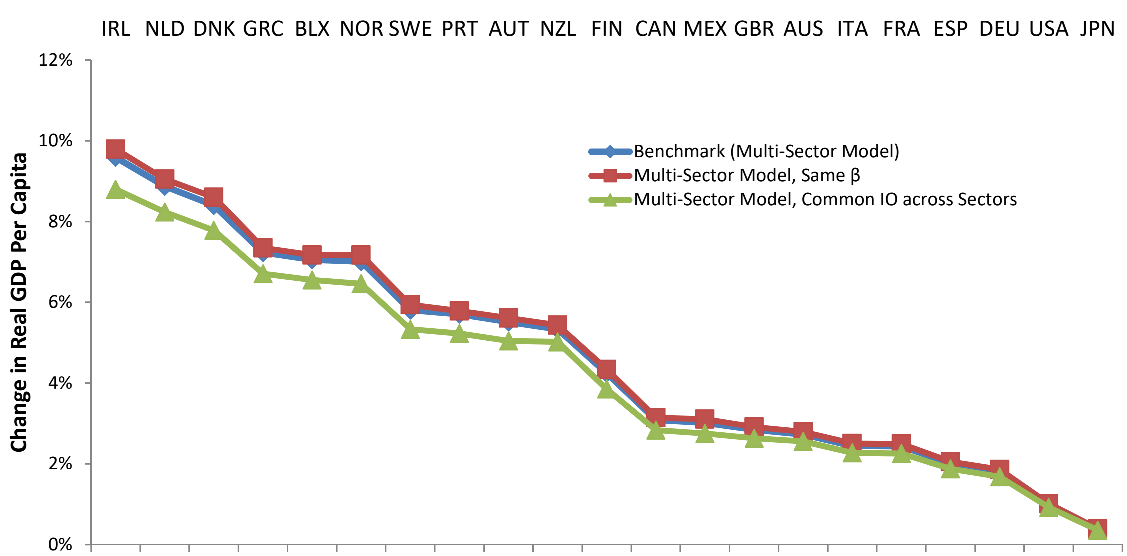


Figure 6: Role of Value-Added, and Input-Output Structure, Heterogeneity in Benchmark Model



output in tradable sectors, β^s's. The benchmark welfare gains illustrated in Figure 1 and shown in column (1) in Table 5 involve sector-specific β^s's. Column (5) in Table 5 depicts the welfare gains for a common value of $\beta = 0.37$ across sectors. Comparing these two columns – also illustrated in Figure 6 – shows that the welfare gains in the common β case are about the same or slightly larger than in the benchmark case. Therefore, the sectoral heterogeneity through sector-specific β's does not result in higher welfare gains. The reason for this is similar to the reason given for the median $1/\theta^s$ case above. Sectors 383 and 384 have value-added shares that are similar to the median β^s. Hence, replacing the sector-specific β^s with the median one will not yield large changes in the GFT.

Finally, we show the effects of heterogeneity in the input-output structure across sectors. We impose a common input-output structure (common ϕ's and ξ's) for all sectors, and then compute the welfare gains relative to autarky. The results can be seen by comparing the benchmark case in column (1) with column (6) in Table 5, and also in Figure 6. The table and figure show that the welfare gains from a common input-output structure are slightly lower than in the benchmark case. Hence, heterogeneity in sectoral input-output structures does not deliver significantly larger gains from trade.

Our main conclusion from this set of counterfactuals is that removing one source of sectoral heterogeneity will yield larger or smaller gains from trade, depending on the source of heterogeneity, relative to the benchmark model. In the exercise involving sectoral trade elasticities, it turns out that the sectoral elasticities interact with the sectoral value-added shares and sectoral home expenditure shares in a way that does not lead to significant gains from trade relative to a framework with a common trade elasticity equal to the median of the sectoral elasticities. We obtain similar results when we replace sector-specific value-added shares and input-output linkages with an average value-added share, or input-output linkage, across sectors.

5 Conclusion

The goal of our paper is to quantitatively assess the role of sectoral heterogeneity in computing the gains from trade. To do so, we employ a 20-sector, 21-country Eaton-Kortum-type

Ricardian trade model that draws from Caliendo and Parro (2015) and Alvarez and Lucas (2007). We estimate the sectoral trade elasticities using micro-price data and the method developed by Simonovska and Waugh (2014). We calibrate the other parameters of the model following Waugh (2010). With our calibrated benchmark model, we first compute the gains from trade relative to autarky. We then conduct a series of counterfactuals by shutting down one or more sources of sectoral heterogeneity. With each counterfactual, we re-calibrate the model so that it is consistent with the trade and output data, and compute the re-calibrated model's gains from trade. A key part of the re-calibration is estimating the trade elasticity. Hence, in each counterfactual we employ model-consistent elasticity estimates. Finally, we compare these gains from trade with that of the benchmark model.

Our primary conclusion from these counterfactuals is that including for more heterogeneity does not necessarily imply higher gains from trade. It depends. In our main comparison of our benchmark multi-sector model with five sources of sectoral heterogeneity against a one-sector model, we find that for most countries, the gains from trade in the benchmark model are slightly lower than in the one-sector model. In this comparison, a key role is played by the sectoral trade elasticities vis-a-vis the one-sector elasticity. When we eliminate the difference in trade elasticities, so that there are only four sources of sectoral heterogeneity, we find that the benchmark model does deliver greater gains from trade than the one-sector model.

In addition, in our simulations in which only the sectoral heterogeneity in the trade elasticities was removed, we find that the gains from trade in the benchmark model were about the same as in the model with no heterogeneity in the trade elasticities. We obtained a similar result when we removed sectoral heterogeneity in the value-added sharers. The main reason for these two results is that for the key sectors, the trade elasticities and value-added shares are similar to the median or average values across all the tradable sectors. All of our results are consistent with the theory – that there should be no presumption that increased heterogeneity leads to increased gains.

We are also able to demonstrate how our results can be consistent with those of Costinot and Rodriguez-Clare (2014) and Ossa (2015). In particular, if we replace our estimated one-sector elasticity with the median of the sectoral elasticity estimates, we obtain results similar to them.

Along the way, we uncovered at least one interesting decomposition from our benchmark model. When the sources of the gains from trade are decomposed into the traditional trade linkages effect, and the intersectoral price effect, we find that the latter is a partial offset to the former, and that non-traded goods play a key role in that. This points to the importance of using frameworks in which non-traded goods are explicitly modeled.

At the end of the day, there is the wisdom that the level of disaggregation and heterogeneity in a quantitative model should depend on the question. However, the nature of the question of the gains from trade suggests that the most disaggregated model with the most heterogeneity should be employed. Our results simply indicate that the increased disaggregation and heterogeneity will not necessarily lead to higher gains from trade calculations.

While our Eaton-Kortum (2002) type framework permits a great deal of heterogeneity, it does not allow for heterogeneity of entry into production as in Melitz (2003), Melitz and Redding (2015), and Simonovska and Waugh (2014b), for example. In addition, modeling the distribution sector, as in Giri (2012), for example, would be useful to more closely map the price data with the model counterparts. These are two avenues for future research.

Table 5: Welfare Gains from Trade

	Multi-Sector Model ($S=19$ Traded Goods Sectors, 1 Non-traded Goods Sector)						One Sector Model (1 Traded Goods Sector (T), 1 Non-traded Goods Sector (N))					
Parameterization	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
θ	Sectoral	8.28	4.38	2.37	Sectoral	Sectoral	2.37	8.28	4.38	4.38	8.28	2.37
β	Sectoral	Sectoral	Sectoral	Sectoral	0.37	Sectoral	0.37	0.37	0.37	0.37	0.37	
γ	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
δ	Sectoral	Sectoral	Sectoral	Sectoral	Sectoral	Sectoral	T, N	T, N	T, N	T, N	T, N	T, N
I-O	20×20	20×20	20×20	20×20	20×20	20×20	2×2	2×2	2×2	2×2	2×2	2×2
	-	-	-	-	-	rows same	-	-	-	diagonal	diagonal	diagonal
Countries												
AUS	2.73%	1.32%	2.46%	4.45%	2.79%	2.56%	3.07%	0.89%	1.68%	1.82%	0.97%	3.34%
AUT	5.52%	2.78%	5.25%	9.72%	5.61%	5.04%	6.71%	1.92%	3.63%	3.95%	2.08%	7.31%
BLX	7.05%	3.62%	6.80%	12.43%	7.17%	6.55%	2.07%	0.60%	1.13%	1.23%	0.65%	2.24%
CAN	3.09%	1.50%	2.86%	5.34%	3.14%	2.83%	4.97%	1.40%	2.67%	2.91%	1.53%	5.43%
DEU	1.82%	0.92%	1.74%	3.23%	1.86%	1.68%	2.81%	0.81%	1.52%	1.65%	0.88%	3.05%
DNK	8.40%	4.39%	8.18%	14.81%	8.60%	7.79%	9.35%	2.76%	5.16%	5.56%	2.99%	10.05%
ESP	2.01%	0.96%	1.83%	3.40%	2.05%	1.88%	3.15%	0.89%	1.69%	1.84%	0.97%	3.43%
FIN	4.25%	2.13%	4.00%	7.34%	4.34%	3.85%	4.66%	1.34%	2.53%	2.75%	1.46%	5.07%
FRA	2.44%	1.19%	2.26%	4.19%	2.49%	2.25%	3.81%	1.09%	2.06%	2.24%	1.18%	4.15%
GBR	2.85%	1.39%	2.61%	4.78%	2.91%	2.63%	4.57%	1.34%	2.50%	2.71%	1.45%	4.95%
GRC	7.23%	3.71%	6.98%	12.69%	7.34%	6.70%	6.97%	1.98%	3.76%	4.10%	2.16%	7.61%
IRL	9.59%	4.94%	9.31%	17.10%	9.79%	8.80%	9.32%	2.68%	5.06%	5.50%	2.91%	10.14%
ITA	2.44%	1.15%	2.19%	4.10%	2.50%	2.27%	3.75%	1.06%	2.01%	2.19%	1.15%	4.09%
JPN	0.38%	0.18%	0.35%	0.65%	0.39%	0.36%	0.47%	0.13%	0.25%	0.27%	0.14%	0.51%
MEX	3.02%	1.42%	2.73%	5.14%	3.10%	2.75%	3.49%	0.98%	1.86%	2.03%	1.06%	3.82%
NLD	8.87%	4.46%	8.41%	15.47%	9.05%	8.24%	11.40%	3.29%	6.20%	6.72%	3.57%	12.37%
NOR	7.01%	3.67%	6.84%	12.40%	7.17%	6.46%	7.81%	2.31%	4.31%	4.65%	2.50%	8.42%
NZL	5.33%	2.72%	5.13%	9.42%	5.44%	5.02%	4.54%	1.30%	2.46%	2.67%	1.42%	4.93%
PRT	5.71%	2.90%	5.46%	10.02%	5.78%	5.23%	6.35%	1.84%	3.46%	3.75%	1.99%	6.88%
SWE	5.81%	2.93%	5.49%	10.04%	5.93%	5.33%	6.89%	2.00%	3.76%	4.08%	2.17%	7.46%
USA	1.00%	0.50%	0.94%	1.75%	1.01%	0.93%	1.58%	0.45%	0.85%	0.92%	0.49%	1.72%
Average	4.60%	2.32%	4.37%	8.02%	4.69%	4.24%	5.13%	1.48%	2.79%	3.03%	1.61%	5.57%
Median	4.25%	2.13%	4.00%	7.34%	4.34%	3.85%	4.57%	1.34%	2.50%	2.71%	1.45%	4.95%
Max	9.59%	4.94%	9.31%	17.10%	9.79%	8.80%	11.40%	3.29%	6.20%	6.72%	3.57%	12.37%
Min	0.38%	0.18%	0.35%	0.65%	0.39%	0.36%	0.47%	0.13%	0.25%	0.27%	0.14%	0.51%

Benchmark model trade costs are increased by a factor of 100 to achieve numerical approximation of autarky ($D^s_{ii} < 1e-6 \ \forall \ i, s$). For sectoral values of β and δ refer to Table 2 . For sectoral values of θ refer to the SMM-PPML column of Table 4. δ^N, of the one sector model, is taken to be equal to $\delta^{f,S+1}$ of the multi-sector model. δ^T, of the one sector model is simply equal to $(1-\delta^N)$.

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6 Appendix

6.1 Appendix A: Price of Sector s Intermediate Composite

The price of sector s composite is given by

$$P_i^s = \left[\int_0^1 p_i^s \left(x^s\right)^{1-\eta^s} dx^s \right]^{\frac{1}{1-\eta^s}} \quad .$$

Let

$$R = p_i^s \left(x^s\right)^{\frac{1}{\theta^s}} \sim \exp\left\{ \left(B^s\right)^{\frac{-1}{\theta^s}} \sum_{j=1}^N \psi_{ij}^s \right\}$$

and

$$M = p_i^s \left(x^s\right)^{1-\eta^s} \quad .$$

Then, R can be written as a function of M:

$$R = R\left(M\right) = M^{\frac{1}{\theta^s\left(1-\eta^s\right)}} \quad .$$

Using

$$f\left(M\right) = f\left(R\left(M\right)\right) \times \left|R'\left(M\right)\right|$$

we can write

$$f\left(M\right) = \exp\left\{ -\left(B^s\right)^{\frac{-1}{\theta^s}} \sum_{j=1}^N \psi_{ij}^s M^{\frac{1}{\theta^s\left(1-\eta^s\right)}} \right\} \frac{M^{\frac{1}{\theta^s\left(1-\eta^s\right)}-1}}{\theta^s\left(1-\eta^s\right)} \quad .$$

Define

$$u = \left(B^s\right)^{\frac{-1}{\theta^s}} \left(\sum_{j=1}^N \psi_{ij}^s \right) M^{\frac{1}{\theta^s\left(1-\eta^s\right)}} \quad ,$$

and hence

$$du = \left(B^s\right)^{\frac{-1}{\theta^s}} \left(\sum_{j=1}^N \psi_{ij}^s \right) \frac{M^{\frac{1}{\theta^s\left(1-\eta^s\right)}-1}}{\theta^s\left(1-\eta^s\right)} dM \quad .$$

Since

$$
\begin{aligned}
(P_i^s)^{1-\eta^s} &= \int_0^\infty M f(M)\, dM \\
&= \int_0^\infty M \exp\left\{ -(B^s)^{\frac{-1}{\theta^s}} \left(\sum_{j=1}^N \psi_{ij}^s \right) M^{\frac{1}{\theta^s(1-\eta^s)}} \right\} \frac{M^{\frac{1}{\theta^s(1-\eta^s)}-1}}{\theta^s(1-\eta^s)} dM \\
&= \left\{ \int_0^\infty u^{\theta^s(1-\eta^s)} \exp(-u)\, du \right\} \left\{ (B^s)^{\frac{-1}{\theta^s}} \sum_{j=1}^N \psi_{ij}^s \right\}^{-\theta^s(1-\eta^s)-1} ,
\end{aligned}
$$

it gives us

$$
P_i^s = A^s B^s \left(\sum_{j=1}^N \psi_{ij}^s \right)^{-\theta^s} = A^s B^s \left(\sum_{j=1}^N \left(V_j^s \tau_{ij}^s \right)^{\frac{-1}{\theta^s}} \lambda_j^s \right)^{-\theta^s} , \tag{6.1}
$$

where $A^s = \left(\widetilde{A}^s(\theta^s, \eta^s) \right)^{\frac{1}{1-\eta^s}}$ and

$$
\widetilde{A}^s(\theta^s, \eta^s) = \left\{ \int_0^\infty u^{\theta^s(1-\eta^s)} \exp(-u)\, du \right\}
$$

is a Gamma function.

6.2 Appendix B: Methodology for Estimating Sector-Level θ's and τ_{ij}'s

Recall that

$$
D_{ij}^s = (A^s B^s)^{-\frac{1}{\theta^s}} \left(\frac{V_j^s \tau_{ij}^s}{P_i^s} \right)^{\frac{-1}{\theta^s}} \lambda_j^s
$$

which implies that

$$
\frac{D_{ij}^s}{D_{jj}^s} = \frac{(A^s B^s)^{-\frac{1}{\theta^s}} \left(\frac{V_j^s \tau_{ij}^s}{P_i^s} \right)^{\frac{-1}{\theta^s}} \lambda_j^s}{(A^s B^s)^{-\frac{1}{\theta^s}} \left(\frac{V_j^s \tau_{jj}^s}{P_j^s} \right)^{\frac{-1}{\theta^s}} \lambda_j^s} = \left(\frac{P_j^s \tau_{ij}^s}{P_i^s} \right)^{\frac{-1}{\theta^s}} .
$$

This corresponds to equation (12) in EK. The log version of this expression can be estimated for each sector individually to obtain $\frac{1}{\theta^s}$'s that correspond to θ in EK (i.e., if we had only one sector, we would have $\frac{1}{\theta^s} = \theta^{EK}$ where θ^{EK} represents θ in EK). The log version can be written as

$$\log\left(\frac{D_{ij}^s}{D_{jj}^s}\right) = -\frac{1}{\theta^s}\log\left(\frac{P_j^s\tau_{ij}^s}{P_i^s}\right) \quad , \tag{6.2}$$

and similar to EK and SW, we use

$$\log\left(\frac{P_j^s\tau_{ij}^s}{P_i^s}\right) = \frac{\max\left\{r_{ij}\left(x^s\right)\right\}}{\sum_{j=1}^{H^s}\left[r_{ij}\left(x^s\right)\right]/H^s} \quad ,$$

where $r_{ij}\left(x^s\right) = \log p_i^s\left(x^s\right) - \log p_j^s\left(x^s\right)$, $\max_x$ means the highest value across goods, and H^s is the number of goods in sector s of which prices are observed in the data. This corresponds to equation (13) in EK.

Using (3.1), we employ two methods to estimate sector-level θ's: (i) method-of-moments (MM) estimator used by EK; (ii) simulated-method-of-moments (SMM) estimator used by SW. While the former is the mean of the left-hand-side variable over the mean of the right-hand-side variable in (3.1), the latter is much more detailed. The SMM estimator can be obtained as follows for each sector s:

1. Estimate θ^s using MM estimator (as in EK) together with trade and price data in (3.1). Call this θ_{EK}^s.

    - Note: this is done for only the EU countries for which we have price data.

2. Estimate gravity equation using the specification employed in SW:

$$\frac{D_{ij}^s}{D_{ii}^s} = \frac{\left(A^sB^s\right)^{-\frac{1}{\theta^s}}\left(\frac{V_j^s\tau_{ij}^s}{P_i^s}\right)^{\frac{-1}{\theta^s}}\lambda_j^s}{\left(A^sB^s\right)^{-\frac{1}{\theta^s}}\left(\frac{V_i^s\tau_{ii}^s}{P_i^s}\right)^{\frac{-1}{\theta^s}}\lambda_i^s} = \left(\frac{V_j^s\tau_{ij}^s}{V_i^s}\right)^{\frac{-1}{\theta^s}}\frac{\lambda_j^s}{\lambda_i^s}$$

   Hence, the log version can be written as:

$$\ln\left(\frac{D_{ij}^s}{D_{ii}^s}\right) = \ln\left(\left(V_j^s\right)^{\frac{-1}{\theta^s}}\lambda_j^s\right) - \ln\left(\left(V_i^s\right)^{\frac{-1}{\theta^s}}\lambda_i^s\right) - \frac{1}{\theta^s}\ln\left(\tau_{ij}^s\right)$$

and can be estimated with fixed effects as follows:

$$\ln\left(\frac{D^s_{ij}}{D^s_{ii}}\right) = T^s_j - T^s_i - \frac{1}{\theta^s}\ln\left(\tau^s_{ij}\right) \quad , \tag{6.3}$$

where

$$T^s_j = \ln\left(\left(V^s_j\right)^{\frac{-1}{\theta^s}}\lambda^s_j\right)$$

and

$$T^s_i = \ln\left(\left(V^s_i\right)^{\frac{-1}{\theta^s}}\lambda^s_i\right)$$

and

$$\ln\tau^s_{ij} = \underbrace{dist_I}_{\text{distance}} + \underbrace{brdr}_{\text{border}} + \underbrace{lang}_{\text{language}} + \underbrace{tblk_G}_{\text{trade block}} + \underbrace{src^s_i}_{\text{source effect}} + \varepsilon^s_{ij} \quad .$$

Since there are zero-trade observations in trade data, we use poisson pseudo maximum likelihood (PPML) estimation as advocated in Silva-Tenreyo (2006).

3. SW show that the inverse of the marginal cost of production (multiplied by B^s) in sector s of country i, which is

$$u^s_i = \frac{1}{z^s_i\left(x^s\right)^{\theta^s}V^s_i}$$

is distributed according to:

$$M^s_i\left(u^s_i\right) = \exp\left(-\left(\exp\left(T^s_i\right)\right)\left(u^s_i\right)^{-1/\theta^s_G}\right)$$

where $T^s_i = \ln\left(\left(V^s_i\right)^{\frac{-1}{\theta^s}}\lambda^s_i\right)$ is the country-fixed effect estimated above.

- This can also be done by using the "inverse transform method". The idea is that probability draws from the $Frechet\left(\exp\left(T^s_i\right), 1/\theta^s\right)$ can be transformed into random draws from a standard uniform distribution. If u has standard uniform distribution then the inverse of the marginal cost is given by

$$\left(\frac{log(u)}{-\exp\left(T^s_i\right)}\right)^{-\theta^s} \quad .$$

  We adopt this method in the code. This is in line with SW.

4. Therefore, for a given θ, say, θ_G^s, we can use source dummies (T_i^s's) in the gravity equation to estimate source marginal costs.

5. Using trade cost $\left(\text{i.e., } \tau_{ij}^s\right)$ and the inverse of the marginal cost of production multiplied by B^s (i.e., u_i^s), we can figure out "possible" destination prices and select the minimum price for each destination:

$$p_i^s\left(x^s\right) = B^s \min_j \left\{ V_j^s z_j^s \left(x^s\right)^{\theta^s} \tau_{ij}^s \right\}$$

These are the simulated equilibrium prices. We allow for $50,000$ possible total goods in each sector and think ourselves as randomly drawing good prices from these pools.

6. Given the simulated equilibrium prices of $p_i^s\left(x^s\right)$'s, the price P_i^s of the sector-level composite index C_i^s can be simulated as follows:

$$P_i^s = \left[\int_0^1 p_i^s \left(x^s\right)^{1-\eta^s} dx^s \right]^{\frac{1}{1-\eta^s}} \quad ,$$

where we use $\eta^s = 2$ following SW. The expenditure of country i on good x imported from country j is simply given by:

$$p_i^s(x^s) q_i^s(x^s) = \left(\frac{p_i^s(x^s)}{P_i^s} \right)^{1-\eta^s} X_i^s \quad ,$$

where X_i^s is the total expenditure by country i on sector s goods, i.e., $X_i^s = P_i^s C_i^s$. Adding this expenditure across all goods imported by i from j, and then dividing both sides by X_i^s gives us the simulated trade share:

$$\widehat{D_{ij}^s} = \frac{X_{ij}^s}{X_i^s} = \int_{\Omega_{ij}} \left(\frac{p_i^s(x^s)}{P_i^s} \right)^{1-\eta^s} dx^s \quad ,$$

where Ω_{ij} is the set of goods imported by country i from country j, and we use $\eta^s = 2$ as in SW.

7. We calculate the trade shares normalized by importing country's own trade share, i.e., $\widehat{D_{ij}^s}/\widehat{D_{ii}^s}$. We take the logarithm of these normalized trade shares and add the residuals

from the gravity equation (with replacement in each simulation). This, thus, gives us the log normalized trade shares with errors. Denote these by $\log\left(D^s_{ij}/D^s_{ii}\right)$. Take the exponential of this to get D^s_{ij}/D^s_{ii}. These are the normalized simulated equilibrium trade shares. Finally, we unwind these normalized trade shares into levels to get D^s_{ij}. To do that, we use that fact that for an importing country i, the sum of its trade shares across all suppliers $j = i, \ldots, N$ is one, i.e., $\sum_{j=1}^{N} D_{ij} = 1$. So, it is implied that $\sum_{j=1}^{N}\left(D^s_{ij}/D^s_{ii}\right) = 1/D^s_{ii}$. Accordingly, we simply divide the normalized trade shares D^s_{ij}/D^s_{ii} by $1/D^s_{ii}$, and that gives us the level trade share D^s_{ij} which, importantly, incorporates the residuals from the gravity equation.

8. Using simulated trade (incorporating the residuals) and simulated prices, estimate θ^s using MM estimator (as in EK) according to:

$$\underbrace{\log\left(\frac{D^s_{ij}}{D^s_{jj}}\right)}_{\text{Simulated Trade Data}} = -\frac{1}{\theta^s_S}\underbrace{\log\left(\frac{P^s_j\tau^s_{ij}}{P^s_i}\right)}_{\text{Simulated Price Data}}$$

which we call as θ^s_S. We repeat this exercise for $1,000$ times.[22]

- This is done for only the EU countries for which we have price data.

9. Within $1,000$ simulated θ^s_S's, we search for θ^s_G, that minimizes the weighted distance between θ^s_{EK} and the average θ^s_S:

$$\theta^s_{SMM} = \arg\min_{\theta^s_G}\left[\left(\theta^s_{EK} - \frac{1}{1000}\sum_{s=1}^{1000}\theta^s_S\right)\mathbf{W}\left(\theta^s_{EK} - \frac{1}{1000}\sum_{s=1}^{1000}\theta^s_S\right)\right]$$

[22]Note that according to

$$\log\left(\frac{P^s_j\tau^s_{ij}}{P^s_i}\right) = \frac{\max\left\{r_{ij}\left(x^s\right)\right\}}{\sum_{j=1}^{H^s}\left[r_{ij}\left(x^s\right)\right]/H^s},$$

where B^s's $\left(\text{as in } p^s_i\left(x^s\right) = B^s\min_j\left\{V^s_j z^s_j\left(x^s\right)^{\theta^s}\tau^s_{ij}\right\}\right)$ cancel each other out while calculating $\log\left(\frac{P^s_j\tau^s_{ij}}{P^s_i}\right)$; therefore, we don't need to know B^s's while estimating θ^s's.

where W is the continuously updated weighting matrix defined as:

$$\mathbf{W} = \frac{1}{1000}\sum_{s=1}^{1000}\theta_S^s\left[\left(\theta_{EK}^s - \frac{1}{1000}\sum_{s=1}^{1000}\theta_S^s\right)\left(\theta_{EK}^s - \frac{1}{1000}\sum_{s=1}^{1000}\theta_S^s\right)\right]$$

We also used an alternative W definitions such as (i) the one used by EKK based on bootstrapping, (ii) an alternative version of W above which is

$$\mathbf{W}_A = \frac{1}{1000}\sum_{s=1}^{1000}\theta_S^s\left[\begin{array}{c}\left(\left(\theta_{EK}^s - \frac{1}{1000}\sum_{s=1}^{1000}\theta_S^s\right) - \frac{1}{1000}\sum_{s=1}^{1000}\left(\theta_{EK}^s - \frac{1}{1000}\sum_{s=1}^{1000}\theta_S^s\right)\right) \\ \times\left(\left(\theta_{EK}^s - \frac{1}{1000}\sum_{s=1}^{1000}\theta_S^s\right) - \frac{1}{1000}\sum_{s=1}^{1000}\left(\theta_{EK}^s - \frac{1}{1000}\sum_{s=1}^{1000}\theta_S^s\right)\right)\end{array}\right]$$

and (iii) the identity matrix; however, the results were very close to each other. Currently, we are using the benchmark W defined above. The selected θ_G^s is the SMM estimate of θ^s, which we denote by θ_{SMM}^s.

Following Eaton, Kortum, and Kramarz (2011) and SW, we calculate standard errors using a bootstrap technique, taking into account both sampling error and simulation error. In particular, we proceed as follows:

1. Using the fitted values and residuals in the gravity equation of (3.3), resample residuals with replacement and generate a new set of data using the fitted values. This is very similar to Step 5 in SMM estimation, above.

2. For each resampling b, with the generated data set, estimate θ^s using MM estimator (as in EK) together with trade and price data in (3.1). Call this θ_b^s.

3. To account for simulation error, set a new seed to generate a new set of model-generated moments; i.e., follow Steps 2-7 for SMM estimation above to estimate $\theta_{b,SMM}^s$ for each bootstrap b.

4. Repeat this exercise 25 times and compute the estimated standard error of the estimate of θ_{SMM}^s as follows:

$$S.E.\left(\theta_{SMM}^s\right) = \left[\frac{1}{25}\sum_{b=1}^{25}\left(\theta_{b,SMM}^s - \theta_{SMM}^s\right)'\left(\theta_{b,SMM}^s - \theta_{SMM}^s\right)\right]^{\frac{1}{2}}$$

where $\theta^{s}_{b,SMM}$ is a vector with the size of (25×1).

6.3 One Sector Eaton-Kortum Model

Here we present the version of our model with one traded goods sector (T). There is continuum of tradable goods $x_i \in [0,1]$ in the traded goods sector of country i, and each good is produced by combining labor and intermediate inputs through a Cobb-Douglas production technology.

$$q_i(x_i) = z_i(x)^{-\theta} [l_i(x)]^{\beta} \left[\prod_{m=\{T,N\}} C_i^m(x)^{\xi^{T,m}} \right]^{1-\beta}$$

The traded goods sector's composite good is given by

$$C_i^T = \left[\int \overline{q}_i(x)^{\frac{\eta-1}{\eta}} f(x)\, dx \right]^{\frac{\eta}{\eta-1}} ,$$

where

$$f(x) = f(z) = \left(\prod_{i=1}^{N} \lambda_i \right) \exp\left(-\sum_{i=1}^{N} \lambda_i z_i \right)$$

Given that the individual goods can be bought from domestic or foreign producers, the price of good x in country i is

$$p_i(x) = \min_j \left\{ BV_j z_j (x_j)^{\theta} \tau_{ij} \right\} \tag{6.4}$$

where V_i, the unit cost of production, is given by

$$V_i = [w_i]^{\beta} \left[\prod_{m=\{T,N\}} (P_i^m)^{\xi^{T,m}} \right]^{1-\beta} , \tag{6.5}$$

and

$$B = (\beta)^{-\beta} (1-\beta)^{-(1-\beta)} \left[\prod_{m=\{T,N\}} \left(\xi^{T,m}\right)^{-\xi^{T,m}} \right]^{(1-\beta)} .$$

Following the steps as outlined in the multi-sector model, the expression for price of traded goods sector composite is given by

$$P_i^T = \left[\int_0^1 p_i(x)^{1-\eta}\,dx\right]^{\frac{1}{1-\eta}} = AB\left(\sum_{j=1}^{N}\psi_{ij}\right)^{-\theta} \tag{6.6}$$

where

$$\psi_{ij} = (V_j\tau_{ij})^{\frac{-1}{\theta}}\,\lambda_j \quad , \tag{6.7}$$

and $A = \left(\int\limits_0^\infty u^{\theta(1-\eta)}\exp(-u)\,du\right)^{\frac{1}{1-\eta}}$ is a Gamma function.

The non-traded sector's homogenous good is produced as follows:

$$C_i^N = A_i^N \left[l_i^N\right]^\gamma \left[\prod_{m=\{T,N\}}\left(C_i^{N,m}\right)^{\phi^{N,m}}\right]^{1-\gamma} \quad ,$$

The price of the non-traded good is

$$P_i^N = E\frac{[w_i]^\gamma\left[\prod_{m=\{T,N\}}(P_i^m)^{\phi^{N,m}}\right]^{1-\gamma}}{A_i^N} \quad , \tag{6.8}$$

where

$$E = \gamma^{-\gamma}(1-\gamma)^{-(1-\gamma)}\left(\prod_{m=\{T,N\}}\left(\phi^{N,m}\right)^{-\phi^{N,m}}\right)^{(1-\gamma)} \quad .$$

The utility of the representative household in each country is given by

$$U_i = Y_i$$

where Y_i, the final consumption good, is a Cobb-Douglas aggregator of the sectoral composite goods.

$$Y_i = \prod_{m=\{T,N\}}\left(C_i^{f,m}\right)^{\delta^{f,m}} \quad ,$$

The price of the final good, therefore, is given by

$$P_i = \prod_{m=\{T,N\}} \left(\delta^{f,m}\right)^{-\delta^{f,m}} \left(P_i^m\right)^{\delta^{f,m}} \quad . \tag{6.9}$$

The market clearing conditions are as follows:

$$\underbrace{\int_0^1 l_i^s\left(x^s\right)dx^s}_{l_i^T} + l_i^N \leq 1 \quad , i = 1, \ldots, N \quad ,$$

$$\underbrace{\int_0^1 C_i^{T,s}\left(x^s\right)dx^s}_{C_i^{T,s}} + C_i^{N,s} + C_i^{f,s} \leq C_i^s \quad , i = 1, \ldots, N \ , \ s = \{T, N\} \quad .$$

Finally, the share of country j in country i's total expenditure on traded goods is:

$$D_{ij} = \frac{X_{ij}^T}{X_i^T} = \pi_{ij} = \frac{\psi_{ij}}{\sum_{n=1}^N \psi_{in}} \quad .$$

Using (6.6), we can rewrite this expression as:

$$D_{ij} = (AB)^{-\frac{1}{\theta}} \left(\frac{V_j \tau_{ij}}{P_i^T}\right)^{\frac{-1}{\theta}} \lambda_j \quad . \tag{6.10}$$

To estimate the gravity equation we sum up the trade flows for a country pair across all sectors to arrive at the aggregate trade flows for the single traded goods sector. Thus, now the gravity equation is estimated as follows:

$$\ln\left(\frac{D_{ij}}{D_{ii}}\right) = T_j - T_i - \frac{1}{\theta}\ln\left(\tau_{ij}\right) \tag{6.11}$$

where trade cost specification is unchanged, except that the source country effect is not sector-specific:

$$\ln \tau_{ij} = \underbrace{dist_I}_{\text{distance}} + \underbrace{brdr}_{\text{border}} + \underbrace{lang}_{\text{language}} + \underbrace{tblk_G}_{\text{trade block}} + \underbrace{src_i}_{\text{source effect}} + \varepsilon_{ij} \quad , \tag{6.12}$$

To estimate θ, we pool good of different sectors together to belong to the single traded goods sector, and then employ the bilateral aggregate trade flows with these pooled prices to carry out the SMM estimation as explained in the multi-sector model. The key equations are:

$$\log\left(\frac{D_{ij}}{D_{jj}}\right) = -\frac{1}{\theta}\log\left(\frac{P_j^T \tau_{ij}}{P_i^T}\right) \quad , \tag{6.13}$$

where

$$\log\left(\frac{P_j^T \tau_{ij}}{P_i^T}\right) = \frac{\max\left\{r_{ij}\left(x\right)\right\}}{\sum\limits_{j=1}^{H}\left[r_{ij}\left(x\right)\right]/H} \quad . \tag{6.14}$$

The solution methodology works in the same manner as for the multi-sector model

Step 1 - Estimate trade costs, τ_{ij}, and country dummies, T_i, using the gravity equation - (6.11) and (6.12).

Step 2 - Compute price of traded goods sector composite using

$$P_i^T = AB\left(\sum_{j=1}^{N} e^{T_j}{\tau_{ij}}^{-\frac{1}{\theta}}\right)^{-\theta} \quad .$$

Step 3 - Taking L_i and D_{ij} from the data, solve for per capita expenditures, X_i^s for $s \in \{T, N\}$, as a function of wage, w_i, and use the balanced trade condition to solve for w_i.

$$L_i X_i^s = \delta^{f,s} w_i L_i + (1-\gamma)\,\phi^{N,s} L_i X_i^N + (1-\beta)\,\xi^{T,s}\sum_{j=1}^{N} L_j X_j^T D_{ji} \quad ,$$

$$\sum_{j=1}^{N} L_j X_j^T D_{ji} = L_i X_i^T \quad .$$

To solve for labor allocations - l_i^T and l_i^N - use

$$L_i w_i l_i^T = \beta\sum_{j=1}^{N} L_j X_j^T D_{ji} \quad ,$$

$$L_i w_i l_i^N = \gamma L_i X_i^N \quad .$$

Step 4 - Lastly, the productivity parameter for country i, λ_i, is obtained using the relationship

$$\Omega_i = (V_i)^{-\frac{1}{\theta}} \lambda_i = e^{T_i} \quad , \tag{6.15}$$

where V_i is the factor cost, given by (6.5).

$$V_i = [w_i]^{\beta} \left[\prod_{m=\{T,N\}} (P_i^m)^{\xi^{T,m}} \right]^{1-\beta} \quad .$$

6.4 Appendix D: Other

Table 6: List of Sectors: ISIC Revision 2

ISIC Code	Sector Description
311	Food products
313,314	Beverages and Tobacco
321	Textiles
322	Wearing apparel, except footwear
323	Leather products
324	Footwear, except rubber or plast
331	Wood products, except furniture
332	Furniture, except metal
341,342	Paper and products and printing and publishing
352	Other chemicals
355	Rubber products
356	Plastic products
361	Pottery, china, earthenware
362	Glass and products
369	Other non-metallic mineral products
371	Iron and steel
381	Fabricated metal products
383	Machinery, electric
384	Transport equipment
400	Non-traded sector

Table 7: Input-Output Structure

Share of Column Sector in Row Sector's Expenditure on Intermediates

For Traded Goods Sectors Expenditure on Intermediates - $\xi^{s,m}$

	311	313,314	321	322	323	324	331	332	341,342	352	355	356	361	362	369	371	381	383	384	400
311	0.1092	0.0062	0.0062	0.0062	0.0062	0.0005	0.0005	0.0017	0.0065	0.0009	0.0009	0.0004	0.0004	0.0004	0.0004	0.0002	0.0002	0.0001	0.0133	0.0207
313,314	0.1092	0.0062	0.0062	0.0062	0.0062	0.0005	0.0005	0.0017	0.0065	0.0009	0.0009	0.0004	0.0004	0.0004	0.0004	0.0002	0.0002	0.0001	0.0133	0.0207
321	0.0002	0.1272	0.1272	0.1272	0.1272	0.0105	0.0105	0.0029	0.0012	0.0096	0.0096	0.0020	0.0020	0.0020	0.0003	0.0002	0.0004	0.0056	0.0013	0.0037
322	0.0002	0.1272	0.1272	0.1272	0.1272	0.0105	0.0105	0.0029	0.0012	0.0096	0.0096	0.0020	0.0020	0.0020	0.0003	0.0002	0.0004	0.0056	0.0013	0.0037
323	0.0002	0.1272	0.1272	0.1272	0.1272	0.0105	0.0105	0.0029	0.0012	0.0096	0.0096	0.0020	0.0020	0.0020	0.0003	0.0002	0.0004	0.0056	0.0013	0.0037
324	0.0002	0.1272	0.1272	0.1272	0.1272	0.0105	0.0105	0.0029	0.0012	0.0096	0.0096	0.0020	0.0020	0.0020	0.0003	0.0002	0.0004	0.0056	0.0013	0.0037
331	0.0006	0.0006	0.0006	0.0006	0.0006	0.1132	0.1132	0.0061	0.0005	0.0045	0.0045	0.0040	0.0040	0.0040	0.0023	0.0030	0.0024	0.0058	0.0073	0.0051
332	0.0006	0.0006	0.0006	0.0006	0.0006	0.1132	0.1132	0.0061	0.0005	0.0045	0.0045	0.0040	0.0040	0.0040	0.0023	0.0030	0.0024	0.0058	0.0073	0.0051
341,342	0.0641	0.0201	0.0201	0.0201	0.0201	0.0252	0.0252	0.4278	0.0415	0.0473	0.0473	0.0568	0.0568	0.0568	0.0180	0.0245	0.0232	0.0106	0.0332	0.0303
352	0.0148	0.1546	0.1546	0.1546	0.1546	0.0345	0.0345	0.0615	0.3691	0.3888	0.3888	0.0659	0.0659	0.0659	0.0529	0.0375	0.0274	0.0147	0.0251	0.0300
355	0.0123	0.0124	0.0124	0.0124	0.0124	0.0184	0.0184	0.0118	0.0168	0.0565	0.0565	0.0060	0.0060	0.0060	0.0035	0.0155	0.0265	0.0225	0.0070	0.0052
356	0.0123	0.0124	0.0124	0.0124	0.0124	0.0184	0.0184	0.0118	0.0168	0.0565	0.0565	0.0060	0.0060	0.0060	0.0035	0.0155	0.0265	0.0225	0.0070	0.0052
361	0.0046	0.0011	0.0011	0.0011	0.0011	0.0043	0.0043	0.0004	0.0016	0.0047	0.0047	0.0649	0.0649	0.0649	0.0039	0.0035	0.0056	0.0037	0.0047	0.0021
362	0.0046	0.0011	0.0011	0.0011	0.0011	0.0043	0.0043	0.0004	0.0016	0.0047	0.0047	0.0649	0.0649	0.0649	0.0039	0.0035	0.0056	0.0037	0.0047	0.0021
369	0.0046	0.0011	0.0011	0.0011	0.0011	0.0043	0.0043	0.0004	0.0016	0.0047	0.0047	0.0649	0.0649	0.0649	0.0039	0.0035	0.0056	0.0037	0.0047	0.0021
371	0.0009	0.0011	0.0011	0.0011	0.0011	0.0305	0.0305	0.0013	0.0061	0.0155	0.0155	0.0106	0.0106	0.0106	0.2511	0.2840	0.0469	0.0755	0.0110	0.0092
381	0.0413	0.0016	0.0016	0.0016	0.0016	0.0656	0.0656	0.0095	0.0195	0.0164	0.0164	0.0111	0.0111	0.0111	0.0393	0.1154	0.0627	0.0447	0.0258	0.0139
383	0.0005	0.0011	0.0011	0.0011	0.0011	0.0022	0.0022	0.0011	0.0029	0.0054	0.0054	0.0044	0.0044	0.0044	0.0213	0.0105	0.3393	0.0666	0.0241	0.0202
384	0.0007	0.0010	0.0010	0.0010	0.0010	0.0016	0.0016	0.0016	0.0008	0.0018	0.0018	0.0048	0.0048	0.0048	0.0178	0.0057	0.0119	0.3630	0.0110	0.0397

For Traded Goods Sectors Expenditure on Intermediates - $\phi^{N,m}$

	311	313,314	321	322	323	324	331	332	341,342	352	355	356	361	362	369	371	381	383	384	400
400	0.6185	0.2700	0.2700	0.2700	0.2700	0.5212	0.5212	0.4448	0.5029	0.3484	0.3484	0.6228	0.6228	0.6228	0.5743	0.4736	0.4121	0.3345	0.7950	0.7735