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Abstract

A common assumption in the quantitative Ricardian international trade literature is that within a country, import shares are equalized across sectors. This assumption is at odds with the data, which show within-country heterogeneity in sectoral import behavior. I build a multi-country, multi-sector general equilibrium Ricardian trade model, in which I include a new extensive and intensive international trade margin at the importing sector level. Counterfactual analysis shows that accounting for within-country sector-specific import behavior is significant for the level of welfare gains from trade. Calibrations based on two cross-country data sources show that a benchmark Ricardian model with equalized import shares across sectors underestimates welfare gains from trade by 13 to 24% on average compared to the model accounting for within-country sectoral import patterns. The benchmark model underestimates the productivity gains of sectors which account for most country-level imports and the spillovers of their productivity gains on other sectors through sectoral linkages.

JEL classification: F10, F11, F14.
Keywords: Gains from trade, Sectoral imports, Proportionality assumption.

1 Introduction

Quantifying the gains from trade is a first-order question in the international trade literature. As summarized in the handbook chapter by Costinot and Rodríguez-Clare (2014), a large class of gravity models can be used to put a number on welfare gains associated with trade liberalization. In particular, the quantitative Ricardian trade literature has provided numerous insights into the underlying sources of welfare gains from trade.[1] Extensions of the Eaton and Kortum (2002) model have shown how multiple sectors, intermediate inputs, and input-output linkages among other factors determine the level of welfare gains associated with trade liberalization (Alvarez and Lucas, 2007; Caliendo and Parro, 2015). These models typically assume that agents (for example sectors) have heterogeneous export behaviors because of trade costs, productivity, or other factors; however, they also implicitly assume that within a country, agents (sectors or final consumers) have a common import behavior. Namely, these models assume that within a country, agents import foreign goods at the same extensive and intensive margin, i.e., from the same set of trading partners and with the same intensity. This assumption is at odds with the growing literature focusing on importers, which has shown that import behavior varies across agents (Antras, Fort, and Tintelnot, 2017; Blaum, Lelarge, and Peters, 2018).

This paper bridges both strands of the literature and evaluates how within-country sectoral import patterns affect welfare gains from trade. This paper's contributions are twofold. It first expands the Ricardian trade model of Caliendo and Parro (2015) by including a new international trade margin, in that import shares vary across sectors within a country. It then uses two data sources, which identify import patterns by sectors, to quantify this new trade margin's impact on the level of welfare gains from trade. Counterfactual analysis shows that accounting for within-country sector-specific import behavior is significant. On average, the benchmark model of Caliendo and Parro (2015) underestimates welfare gains from trade by 13 to 24% compared to the augmented model accounting for within-country sectoral import patterns. The benchmark model is shown to underestimate the productivity gains of sectors which account for most country-level imports through their access to foreign cheap inputs, and the spillovers of their productivity gains on other sectors through sectoral linkages.

The theoretical framework follows the multi-country multi-sector Ricardian model of Caliendo and Parro (2015), in which I introduce trade costs that depend on the destination sector. This new feature induces within-country variation in import shares across sectors. The augmented model thus accounts for a new international trade margin at the importing sector

[1] Valuable contributions to the understanding of the drivers of gains from trade go beyond the Ricardian trade literature. Section 2 gives an overview of the literature.

level. The new margin is both extensive and intensive. Within the same country, sectors may differ not only in the number of trading partners but also in how much they buy from a trading partner. The augmented model yields tractable predictions. In particular, as in the benchmark model, the welfare change can be decomposed in a final goods effect, an intermediate goods effect, and a sectoral linkages effect.

I show how the augmented model's welfare predictions differ from the benchmark in a symmetric two-country two-sector toy framework. To do so, I quantify the augmented toy model under varying allocations of imports among sectors and compare them to the corresponding benchmark toy model. This exercise, although highly stylized, highlights three patterns. First, the augmented model's predictions can be either lower or higher than those of the benchmark model. Second, whether welfare gains are higher or lower will be strongly influenced by the allocation of imports to the tradable sector. As the tradable sector's import share increases, the augmented model's welfare gains increase. Third, higher welfare gains in the augmented model are driven by the intermediate goods and sectoral linkages effects. A higher intermediate goods effect is due to the tradable sector: a larger openness of the tradable sector to international trade leads to higher productivity gains. The larger sectoral linkages effect is due to the non-tradable sector: productivity gains of the tradable sector have spillovers on the non-tradable sector through the input-output structure.

I then bring the augmented model to the data. A difficulty in doing so is the lack of data that identify sectors' imports across countries in a consistent manner. Most cross-country databases, in which imports by sectors are available, rely on a proportionality assumption: the same fixed percentage of a product's total use is assumed to be imported, irrespective of its purchaser. The proportionality assumption is consistent with within-country equalized import shares across sectors, which are implicitly assumed in most quantitative Ricardian trade models including Caliendo and Parro (2015). But it is at odds with the importing sector-specific data needed to calibrate the augmented model.

Given these limitations, I use two databases which construct sector-to-sector trade flows without relying on the proportionality assumption. The main data source is the Asian Input-Output Tables (AIOT) published by IDE-JETRO, which record bilateral sector-to-sector trade flows for nine Asian countries, plus the US.[2] The crucial feature of the AIOT is to be survey-based. This allows for the construction of sector-specific import shares. Because the AIOT cover a limited number of countries, I complement the analysis by using the World Input-Output Tables (WIOT). The WIOT only partially rely on the proportionality assumption and cover the

[2]IDE-JETRO stands for Institute of Developing Economies - Japan External Trade Organization.

world's major economies. Using both data sources, I construct two sets of trade shares: *augmented* trade shares, which account for sectoral import behavior, and *benchmark* trade shares, which are aggregated and equalized across sectors within a country.

Both data sources reveal systematic sectoral import patterns that the benchmark trade shares cannot account for and that are at odds with the proportionality assumption. Relying on benchmark trade shares overestimates the extensive margin of sectoral import behavior, while it underestimates the intensive trade margin of the largest importing sectors (in terms of import value). Namely, the benchmark trade shares assign positive trade to sectors that do not import from some trading partners and underestimate the import shares of those sectors with account for most of country-level imports. In addition, both data sources suggest that sectors with high import intensity also have high export intensity.[3] Trade – both exports and imports – is thus concentrated in a few sectors.

Using 2005 data for both sources, the main quantitative exercise evaluates the welfare gains from trade associated with moving from a world without international trade to the observed equilibrium. The calibration approach is standard and relies on the "exact hat algebra" approach as in Dekle, Eaton, and Kortum (2008). Under each calibration, I compare the augmented model's predictions to the Caliendo and Parro (2015) benchmark.

The augmented model's results show several robust deviations from the benchmark. First, the benchmark model predicts lower welfare gains from trade. On average, country-level welfare gains from trade are 24% lower in the benchmark than in the augmented model under the AIOT calibration and 13% lower under the WIOT calibration. This pattern holds for all countries under each calibration. Second, the augmented model's results show strong sectoral patterns. Sectors with a large exposure to foreign markets (which import a large share of their inputs and are export-intensive) show higher contributions to aggregate welfare gains in the augmented model. Most of this effect is explained by a larger intermediate goods effect, implying that these sectors benefit more from their access to foreign cheap inputs in the augmented model. Sectors with a low exposure to foreign markets, e.g., non-tradable sectors, still contribute to the higher aggregate welfare gains in the augmented model. This effect is largely driven by a larger sectoral linkages effect. Even though trade is concentrated in a few open sectors, significant productivity gains in such sectors have positive spillovers on other, less open sectors through the input-output structure.

This paper is structured as follows. Section 2 gives a literature overview.

[3]Export intensity is defined as the ratio of sectoral exports to production, weighted by the destination importing sector. Import intensity is defined as the ratio of sectoral imports to spending, weighted by the origin sector. Both concepts are defined in detail in Section 5.

Section 3 presents the theoretical framework and how it deviates from the Caliendo and Parro (2015) benchmark. Section 4 illustrates the augmented model's predictions compared to the benchmark in a simple symmetric two-sector two-country framework. Section 5 introduces the two cross-country data sources and examines their characteristics. Section 6 presents the augmented and benchmark models' calibrations as well as the counterfactual analysis. Section 7 concludes.

2 Related literature

This paper builds on the quantitative Ricardian international trade literature, which has highlighted the determinants of welfare gains from trade, e.g., multiple sectors, sectoral linkages, variation in trade elasticity, or multinational production (Eaton and Kortum, 2002; Alvarez and Lucas, 2007; Dekle et al., 2008; Caliendo and Parro, 2015; Rodríguez-Clare and Ramondo, 2013). I contribute to this literature by introducing variation in import shares across sectors and thus by taking into account an additional international trade margin. This paper further adds to the literature investigating the sources of Ricardian comparative advantage and how the ability of a sector to access cheap inputs affects comparative advantage (Costinot, Donaldson, and Komunjer, 2012; Chor, 2010).

Beyond the Ricardian approach, a broad literature has explored the sources of gains from trade. In particular, extensions of Melitz (2003) have for example shown how asymmetric trade barriers, new consumers, varieties, and multinational production determine gains from trade (Chaney, 2008; Arkolakis, 2010; Arkolakis, Demidova, Klenow, and Rodríguez-Clare, 2008; Arkolakis, Ramondo, Rodríguez-Clare, and Yeaple, 2018).

Considering both approaches, the handbook chapter of Costinot and Rodríguez-Clare (2014) gives a broad overview of the literature looking at quantifying the welfare gains from trade. Arkolakis, Costinot, and Rodríguez-Clare (2012) show that a broad class of trade models make similar predictions for the level of welfare gains from trade. Such models include the contributions of Armington (1969) and Krugman (1980), as well as extensions of Eaton and Kortum (2002) and Melitz (2003).

This paper further complements the literature on imports, which has analyzed the effect of imports on productivity and prices (Halpern, Koren, and Szeidl, 2015; Gopinath and Neiman, 2014) and more recently studied firm-level heterogeneity in imports. For example, Antras, Fort, and Tintelnot (2017) develop a quantifiable multi-country sourcing model in which firms self-select into importing based on their productivity and on country-specific variables. Blaum, Lelarge, and Peters (2018) develop a methodology to measure the aggregate effects of input trade that takes firm-level heterogeneity in import shares into account and characterize the bias in welfare predictions of approaches relying on aggregate import shares. This paper is closely related to theirs as it considers another source of bias, namely sectoral rather than firm-level heterogeneity in import shares.

This paper further relates to a rich international trade literature based on input-output analysis. Starting with the seminal work of Leontief (1941), empirical papers have studied input trade (Johnson and Moxnes, 2013; Johnson and Noguera, 2012), vertical specialization (Hummels, Ishii, and Kei-Mu, 2001), country and industry downstreamness in global value chains (Antras, Chor, Fally, and Hillberry, 2012; Fally, 2012), the geography and organization of global value chains (Antras and Chor, 2013; Antras and de Gortari, 2017), trade in value added and the factor content of trade (Trefler and Zhu, 2010; Koopman, Wang, and Wei, 2014), as well as specialized input-output linkages (De Gortari, 2017). Within this literature, this paper is related to the study by Puzzello (2012). She uses the AIOT to highlight the bias induced by the proportionality assumption when measuring the factor content of trade. This paper thus shows another dimension of the bias induced by the proportionality assumption by considering the quantification of welfare gains from trade.

3 The margin of importing sectors in a quantitative Ricardian trade model

I build a quantitative general equilibrium international trade model following Caliendo and Parro (2015), a multi-sector extension of Eaton and Kortum (2002), in which I introduce a new international trade margin at the importing sector level. There are N countries, indexed by n for destinations or i for origins. There are S sectors. By assumption, sectors are either tradable or non-tradable. Tradable sectors can export and can be thought of as agriculture or manufacturing sectors. Non-tradable sectors cannot export and can be thought of as services. Unless otherwise noted, b indexes the importing sector and s the exporting sector.

In the rest of this paper, I denote as benchmark the model of Caliendo and Parro (2015) and as augmented the model which accounts for within-country variation in sectoral import patterns.

3.1 Consumer preferences

Country i is populated with L_i homogeneous consumers. They supply one unit of labor in exchange for a wage w_i. Labor is perfectly mobile across sectors within countries, but immobile across countries. Consumers spend a fixed income share on goods from any given sector. Formally, they have

Cobb-Douglas preferences over S sectors given by

$$Q_i = \prod_{s=1}^{S} (Q_i^{sf})^{\beta^s}, \tag{1}$$

where f denotes final expenditure, $0 < \beta^s < 1$ is the share of sector s in consumer expenditure with $\sum_{s=1}^{S} \beta^s = 1$, and Q_i^{sf} is the composite final good of sector s aggregated over a continuum of goods $\omega \in [0, 1]$ given by

$$Q_i^{sf} = \Big[\int_0^1 q_i^{sf}(\omega)^{\frac{\sigma^s - 1}{\sigma^s}} d\omega \Big]^{\frac{\sigma^s}{\sigma^s - 1}},$$

where $\sigma^s > 1$ is the elasticity of substitution for goods of sector s.

Given the Cobb-Douglas consumer preferences, the aggregate consumer price index P_n in country n is given by

$$P_n = \prod_{s=1}^{S} \Big(\frac{P_n^{sf}}{\beta^s} \Big)^{\beta^s}, \tag{2}$$

where P_n^{sf} is the price of the composite final good supplied by sector s.

3.2 Production

Markets are perfectly competitive. Prices equal costs. In any sector s of country i, a representative producer produces the composite good at minimum costs. In country i, the composite good of sector s is used by consumers for final consumption f or by producers of any sector b for intermediate consumption. Unlike the benchmark, the framework allows the composite good Q_i^{sb} to depend on the supplying sector s and on the buying sector b or the final consumer f. To produce the composite good, the representative producer in sector s uses a continuum of goods $\omega \in [0, 1]$.

In sector s of country i, any good ω is produced under perfect competition. Production follows a Cobb-Douglas production function with constant returns to scale given by

$$x_i^s(\omega) = z_i^s(\omega) l_i^s(\omega)^{\alpha^s} \prod_{k=1}^{S} [Q_i^{ks}(\omega)]^{(1-\alpha^s)\rho^{ks}}, \tag{3}$$

where $z_i^s(\omega)$ is the productivity of sector s in country i for the production of good ω, $0 < \alpha^s < 1$ is the value added share of sector s, $0 \leq \rho^{ks} \leq 1$ is the share of inputs bought by sector s from sector k, with $\sum_{k=1}^{S} \rho^{ks} = 1$. Producers use labor l_i^s and demand the composite intermediate good of sector k aggregated over a continuum of goods $\omega \in [0, 1]$ given by

$$Q_i^{ks} = \Big[\int_0^1 q_i^{ks}(\omega)^{\frac{\sigma^k - 1}{\sigma^k}} d\omega \Big]^{\frac{\sigma^k}{\sigma^k - 1}},$$

where $\sigma^k > 1$ is the elasticity of substitution for inputs from sector k.

The productivity of sector s in country i for the production of good ω, $z_i^s(\omega)$, is drawn from a Fréchet distribution with cumulative distribution function

$$F_i^s(z) = \exp(-T_i^s z^{-\theta^s}), \tag{4}$$

where $T_i^s > 0$ is the average productivity of goods produced by sector s in country i and $\theta^s > 0$ is the productivity dispersion in sector s, with low θ^s associated with high dispersion in productivity.

Given perfectly competitive markets, producers produce any good ω at minimum costs. Based on the production function of equation (3), the unit cost of good ω is $c_i^s / z_i^s(\omega)$, where the corresponding input bundle cost c_i^s is given by

$$c_i^s = \lambda^s w_i^{\alpha^s} \prod_{k=1}^{S} \left(P_i^{ks} \right)^{(1-\alpha^s)\rho^{ks}}, \tag{5}$$

where $\lambda^s = (\alpha^s)^{-\alpha^s} \prod_{k=1}^{S} \Big[(1-\alpha^s)\rho^{ks} \Big]^{-(1-\alpha^s)\rho^{ks}}$ is a constant, w_i is the wage rate in country i, and P_i^{ks} is the price of the composite intermediate good supplied by sector k to sector s. Given that sectors buy different composite intermediate goods, they also face different prices as buyers.

3.3 Demand for final and intermediate goods

The consumer preferences and production functions are two-tiered. The outer-tier is Cobb-Douglas: consumers demand a share β^s of the composite good supplied by sector s, and producers of sector b demand a share $(1 - \alpha^b)\rho^{sb}$ of the composite good supplied by sector s.

The inner tier of the consumer preferences and production functions is CES. The demand by producers of sector b or by final consumers $b = f$ for good ω of sector s is

$$q_n^{sb}(\omega) = \Big(\frac{p_n^{sb}(\omega)}{P_n^{sb}} \Big)^{-\sigma^s} Q_n^{sb},$$

where $p_n^{sb}(\omega)$ is the price at which agents b buy good ω from sector s and P_n^{sb} is the price of the composite good of sector s for agents b, given by

$$P_n^{sb} = \Big(\int_0^1 p_n^{sb}(\omega)^{1-\sigma^s} d\omega \Big)^{\frac{1}{1-\sigma^s}}.$$

To simplify the notation, the rest of this paper considers final demand as the $S+1$ importing sector.

3.4 International trade

Within a sector, goods are perfectly substitutable. For any good ω, consumers and producers compare prices across source countries and buy goods from the cheapest supplying country. Formally, sector b's producers (or final consumers) in country n buy good ω from sector s at price

$$p_n^{sb}(\omega) = \min_i \Big[\frac{c_i^s \kappa_{in}^{sb}}{z_i^s(\omega)}\Big], \tag{6}$$

where κ_{in}^{sb} is the iceberg trade cost between origin i and destination country n, and between selling sector s and buying sector b, with $\kappa_{in}^{sb} \geq 1$ for any $n \neq i$ and $\kappa_{in}^{sb} = 1$ if $n = i$. If a sector is non-tradable, $\kappa_{in}^{sb} = \infty$ for any $n \neq i$ and $\kappa_{in}^{sb} = 1$ if $n = i$.

International trade is costly. As in the benchmark model, the trade cost depends on the exporting country i and importing country n, as well as the exporting sector s. The trade cost thus depends on bilateral characteristics, such as distance, and also on factors associated with the type of good being traded, for example tariffs. The main deviation from the benchmark model is to assume that the trade cost further depends on the importing sector b. For this paper's purpose, I remain agnostic on the source of variation in trade costs across importing sectors.[4] This simple approach creates distortions in prices and import shares across sectors within a country.

Following Eaton and Kortum (2002), the assumption that productivity draws follow a Fréchet distribution generates a closed-form solution for prices and trade shares. The price of the composite good supplied by sector s to buyers in sector b in country n is

$$P_n^{sb} = \zeta^s \Big(\sum_{i=1}^{N} T_i^s (c_i^s \kappa_{in}^{sb})^{-\theta^s} \Big)^{-\frac{1}{\theta^s}}, \tag{7}$$

where $\zeta^s = \Gamma(\frac{\theta^s + 1 - \sigma^s}{\theta^s})^{\frac{1}{1-\sigma^s}}$ is a constant, requiring the restriction: $\theta^s + 1 > \sigma^s$.

[4] Several microfoundations of such trade costs may be suggested. For example, one approach would be to follow the work of De Gortari (2017), who shows evidence that suppliers of intermediate inputs produce specialized products that are only compatible with specific downstream uses. This approach is at odds with the assumption that import shares are equalized across importing sectors. The welfare gains predictions, in which inputs are tailored to end-use (assuming an end-sector specific technology T_i^{sb} rather than an end-use specific trade cost), would be equivalent to the augmented model. The aggregate data used in the calibration cannot separately identify the trade costs from the technology parameters.

The trade share between sector b of country n and sector s of country i is the expenditure share on country i's goods in total expenditure by country n's sector b on goods from sector s. It is given by

$$\pi_{in}^{sb} = \frac{T_i^s [c_i^s \kappa_{in}^{sb}]^{-\theta^s}}{\sum_{o=1}^{N} T_o^s (c_o^s \kappa_{on}^{sb})^{-\theta^s}}. \tag{8}$$

The trade share takes the form of a gravity equation, where the importing sector-specific trade cost creates within-country variation in import shares across sectors.[5] Because of the underlying trade costs, sectors within the same country have different sets of trading partners and different import intensities, which translate into different price and cost structures.

3.5 Equilibrium

The equilibrium requires the following goods market and labor income clearing conditions. Let $I_n = w_n L_n$ be labor income and Y_n^s total production of sector s in country n.

Goods market clearing requires that total production of sector s in country i equals total supply worldwide. For any sector s, it must hold

$$Y_i^s = \sum_{n=1}^{N} \Big(\pi_{in}^{sf} \beta^s I_n + \sum_{b=1}^{S} \pi_{in}^{sb} (1 - \alpha^b) \rho^{sb} Y_n^b \Big). \tag{9}$$

The labor market clearing requires that total labor income equals total value added. Formally, it must hold

$$I_n = \sum_{s=1}^{S} \alpha^s Y_n^s. \tag{10}$$

By assumption, international trade is balanced.

3.6 Solving the model in changes

Like in other general equilibrium Ricardian models, it is difficult to calibrate the model in levels: underlying parameters are hard to identify in aggregate data. To simplify the calibration, Dekle, Eaton, and Kortum (2008) first proposed to solve the model in relative changes, rather than in levels, using the "exact hat algebra" approach. Based on this method, the counterfactual equilibrium resulting from any change in underlying fundamentals may be calculated with little data requirements.

Let $\hat{x} = \frac{x'}{x}$ be the ratio of counterfactual x' to the initial value of variable x. Following any change in the exogenous variables (e.g., technology parameters, trade costs), the change in the price of the composite good supplied

[5] Appendix A gives detailed derivations.

by sector s to sector $b = 1, \dots, S+1$ in country n can be expressed as a function of the relative change in trade costs and input bundle costs as well as the initial levels of trade shares. Formally, it holds

$$\hat{P}_n^{sb} = \Big(\sum_{i=1}^{N} \pi_{in}^{sb} (\hat{c}_i^s \hat{\kappa}_{in}^{sb})^{-\theta^s} \Big)^{-\frac{1}{\theta^s}}, \tag{11}$$

where the change in the input bundle cost of sector s in country i $\hat{c}_i^s$ is

$$\hat{c}_i^s = \hat{w}_i^{\alpha^s} \prod_{k=1}^{S} \left(\hat{P}_i^{ks} \right)^{(1-\alpha^s)\rho^{ks}}. \tag{12}$$

The counterfactual trade shares can be expressed as a function of the change in wages, input bundle costs, and bilateral trade costs as well as the initial trade shares. Formally, the counterfactual import share of sector $b = 1, \dots, S+1$ in country n from sector $s = 1, \dots, S$ in country i is given by

$$\pi_{in}^{sb\,\prime} = \frac{\pi_{in}^{sb} (\hat{c}_i^s \hat{\kappa}_{in}^{sb})^{-\theta^s}}{\sum_{o=1}^{N} \pi_{on}^{sb} (\hat{c}_o^s \hat{\kappa}_{on}^{sb})^{-\theta^s}}. \tag{13}$$

The counterfactual goods and labor market conditions can be solved building on equations (11) to (13). The counterfactual supply of manufacturing goods in each sector $Y_i^{s\,\prime}$ and counterfactual labor income I_i' satisfy

$$Y_i^{s\,\prime} = \sum_{n=1}^{N} \Big(\pi_{in}^{sf\,\prime} \beta^s I_n' + \sum_{b=1}^{S} \pi_{in}^{sb\,\prime} (1-\alpha^b) \rho^{sb} Y_n^{b\,\prime} \Big), \tag{14}$$

and

$$I_n' = \sum_{s=1}^{S} \alpha^s Y_n^{s\,\prime}. \tag{15}$$

The counterfactual equilibrium resulting from a change in underlying fundamentals is thus characterized by a wage vector, $[\hat{w}_1, \dots, \hat{w}_N]$, which solves equations (11) to (15).

3.7 Welfare

The counterfactual analysis studies the welfare change associated with moving from some observed equilibrium to a world without international trade. As in a large class of trade models, the welfare change is given by the change in real wage. Formally, the change in real wage in country n following a shock to fundamentals can be written as

$$
\begin{aligned}
\frac{\hat{w}_n}{\hat{P}_n} = & \underbrace{\prod_{s=1}^{S} (\hat{\pi}_{nn}^{sf})^{-\frac{\beta^s}{\theta^s}}}_{\text{Final goods}} \underbrace{\left[\prod_{s=1}^{S} \prod_{k=1}^{S} (\hat{\pi}_{nn}^{ks})^{-\frac{\rho^{ks}}{\alpha^k \theta^k}} \right]^{\beta^s (1-\alpha^s)}}_{\text{Intermediate goods}} \\
& \underbrace{\prod_{s=1}^{S} \prod_{k=1}^{S} \prod_{j=1}^{S} \left[\hat{P}_n^{jk} / \hat{P}_n^{ks} \right]^{-\rho^{jk} \frac{1-\alpha^k}{\alpha^k} \rho^{ks} \beta^s (1-\alpha^s)}}_{\text{Sectoral Linkages}} .
\end{aligned}
\tag{16}
$$

As in Caliendo and Parro (2015), the change in real wage can be expressed as a function of changes in domestic expenditure shares and sectoral price indexes. It can be decomposed in a final goods effect, an intermediate goods effect, and a sectoral linkages effect. However, departing from Caliendo and Parro (2015), equation (16) depends more intricately on the import shares by importer type and on the sector-specific access to inputs. To see how this is the case, it is useful the decompose equation (16) at the sector level.

The contribution of sector s to the change in country n's real wage depends on the change in sectoral prices. Formally, it is given by

$$
\begin{aligned}
\frac{\hat{w}_n}{\hat{P}_n^{sf}} = & \underbrace{\left(\hat{\pi}_{nn}^{sf} \right)^{-\frac{1}{\theta^s}}}_{\text{Final goods}} \underbrace{\left[\prod_{k=1}^{S} (\hat{\pi}_{nn}^{ks})^{-\frac{\rho^{ks}}{\alpha^k \theta^k}} \right]^{1-\alpha^s}}_{\text{Intermediate goods}} \\
& \underbrace{\prod_{k=1}^{S} \prod_{j=1}^{S} \left[\hat{P}_n^{jk} / \hat{P}_n^{ks} \right]^{-\rho^{jk} \frac{1-\alpha^k}{\alpha^k} \rho^{ks} (1-\alpha^s)}}_{\text{Sectoral Linkages}} .
\end{aligned}
\tag{17}
$$

Weighting equation (17) with share β^s and multiplying across sector s yields equation (16).

Based on equation (17), each effect may be more easily interpreted. Sector s's contribution to the aggregate welfare change is first determined by the final goods effect, which is given by the change in the consumer domestic expenditure share $\hat{\pi}_{nn}^{sf}$ and the sectoral trade elasticity θ^s. Following an increase in trade costs, the final goods effect captures the welfare change due to a change in direct final imports by consumers, and thus the loss of foreign, more productive (cheaper) varieties. The intermediate goods effect captures the welfare effect of intermediate goods *imported* by sector s. The intermediate goods effect depends on the change in the domestic expenditure share $\hat{\pi}_{nn}^{ks}$ across all supplying sectors k. Following an increase in trade costs, it reflects the change in productivity of intermediate inputs for some sector s. The more open sector s is, the more it may lose in terms of access to cheap inputs: the change in the sector s's home expenditure share on any sector k $\hat{\pi}_{nn}^{ks}$ is weighted by the relevant input-output linkage ρ^{ks} and by the sectoral trade elasticity of sector k θ^k. The sectoral linkages effect captures relative price changes. For example, welfare losses driven by sector s are accentuated if its supplying sectors face larger productivity losses (i.e., larger price increases). In contrast, welfare losses may be attenuated if supplying sectors face lower productivity losses.

The contribution of sector s to the total welfare change broadly captures the change in sectoral productivity, and encompasses not only how much consumers buy directly from foreign countries in that specific sector, but also how open the domestic sector s is to the rest of the world and its capacity to source inputs from abroad. The contribution of sector s includes direct input trade effects and indirect general equilibrium effects.

3.8 Comparison to the benchmark model

The quantitative analysis compares the augmented model outlined above to the Caliendo and Parro (2015) benchmark. The augmented model boils down to the benchmark under the assumption that trade costs do not vary with the importing sector, i.e., $\kappa_{in}^{sb} = \kappa_{in}^{s}$ for all $b = 1, \ldots, S+1$. Given this assumption, the price of the composite good supplied by sector s is given by

$$P_n^s = \zeta^s \Big(\sum_{i=1}^{N} T_i^s (c_i^s \kappa_{in}^s)^{-\theta^s} \Big)^{-\frac{1}{\theta^s}}, \tag{18}$$

where the input bundle cost c_i^s is

$$c_i^s = \lambda_s w_i^{\alpha^s} \prod_{k=1}^{S} \left(P_i^k \right)^{(1-\alpha^s)\rho^{ks}}.$$

In the benchmark model, all sectors and consumers within a country buy the composite good of sector s at the same price.

The trade share between country n and sector s of country i is given by

$$\pi_{in}^s = \frac{T_i^s [c_i^s \kappa_{in}^s]^{-\theta^s}}{\sum_{o=1}^{N} T_o^s [c_o^s \kappa_{on}^s]^{-\theta^s}}, \tag{19}$$

for all importing agents b and is thus constant across importing sectors within a triplet of the origin country, origin sector, and destination country.

The benchmark model can be solved in changes and the welfare change can be written as

$$\frac{\hat{w}_n}{\hat{P}_n} = \underbrace{\prod_{s=1}^{S} (\hat{\pi}_{nn}^{s})^{-\frac{\beta^s}{\theta^s}}}_{\text{Final goods}} \underbrace{\left[\prod_{s=1}^{S} \prod_{k=1}^{S} (\hat{\pi}_{nn}^{k})^{-\frac{\rho^{ks}}{\alpha^k \theta^k}} \right]^{\beta^s(1-\alpha^s)}}_{\text{Intermediate goods}}$$
$$\underbrace{\prod_{s=1}^{S} \prod_{k=1}^{S} \prod_{j=1}^{S} \left[\hat{P}_n^j / \hat{P}_n^k \right]^{-\rho^{jk} \frac{1-\alpha^k}{\alpha^k} \rho^{ks} \beta^s (1-\alpha^s)}}_{\text{Sectoral Linkages}}. \tag{20}$$

Equation (20) thus follows a similar structure as equation (16).[6]

4 Model predictions in a two-country two-sector framework

The welfare predictions of the augmented and benchmark model cannot be compared in an analytically tractable solution. Instead, I illustrate the predictions of each model within a two-country two-sector framework. This section first presents the toy framework's quantification, then analyzes the augmented model's welfare predictions compared to the Caliendo and Parro (2015) benchmark.

4.1 Quantification of the toy framework

The framework has two symmetric countries and two sectors $k \in \{m, s\}$. The first sector, denoted by m, is tradable and can be thought of as the manufacturing sector. The second sector, denoted by s, is non-tradable and can be thought of as services. Within this simple framework, I calibrate the augmented and benchmark models. For each model, the calibration follows the standard approach in the quantitative Ricardian trade literature and is consistent with the main calibration exercise of Section 6.

The calibration of consumer preferences and production function parameters holds for both augmented and benchmark models. These parameters are calibrated to the average value across countries based on the World Input-Output Tables (WIOT).[7] Table 1 summarizes the calibrated parameters. On average, consumers spend 30% of their labor income on goods from the tradable sector and 70% on goods from the non-tradable sector ($\beta^m = 0.3$ and $\beta^s = 0.7$). The tradable sector's value added share α^m is 0.3,

[6] Equation (20) differs slightly from the formulation of the change in real wage given by Caliendo and Parro (2015). Aggregate gains at the country level are equal, but the allocation of those gains across the final goods effect, the intermediate goods effect, and the sectoral linkages effect, as well as across sectors may differ. Appendix A derives the benchmark model in detail.

[7] The next section introduces the WIOT in detail.

while the non-tradable sector's value added share α^s is 0.5. The tradable sector sources 70% of inputs from the tradable sector and 30% from the non-tradable sector ($\rho^{mm} = 0.7$ and $\rho^{sm} = 0.3$). The non-tradable sector sources 40% of inputs from the tradable sector and 60% from the non-tradable sector ($\rho^{ms} = 0.4$ and $\rho^{ss} = 0.6$). I set the tradable sector's trade elasticity to $\theta^m = 4.1$ following Simonovska and Waugh (2013) and the non-tradable sector's trade elasticity to $\theta^s = 5$ following Caliendo and Parro (2015).

Table 1: Calibration of the toy framework

Parameter/Moment		Sector: Tradable (m)	Sector: Non-tradable (s)
β^k	Consumer spending shares	0.3	0.7
α^k	Sectoral value added share	0.3	0.5
ρ^{km}	Input-output linkages of the tradable sector	0.7	0.3
ρ^{ks}	Input-output linkages of the non-tradable sector	0.4	0.6
θ^k	Trade elasticity	4.1	5
π^m	Benchmark import share	0.2	0.2
π^{mk}	Augmented import share	$[0; 0.6]$	$[0; 0.3]$

Notes: The table reports the calibrated values of parameters or moments under the two-country two-sector framework.
Sources: WIOT, Simonovska and Waugh (2013), Caliendo and Parro (2015).

The augmented model's calibration deviates from the benchmark only in one aspect: the trade shares. I assume that each country imports 20% of tradable goods from the foreign country. This is close to the US aggregate import share based on the WIOT. I thus set the benchmark import share to $\pi^m = 0.2$. Keeping aggregate trade value fixed, I calibrate the augmented trade share under several assumptions regarding the allocation of imports across sectors. At one extreme, I assume that the tradable sector does not export to the foreign tradable sector. This implies $\pi^{mm} = 0$. Instead, the tradable sector exports exclusively to the foreign non-tradable sector and to the foreign final consumers, which implies $\pi^{ms} > 0$ and $\pi^{mf} > 0$. Keeping aggregate trade fixed, this scenario corresponds to a world, in which the non-tradable sector buys 30% of its tradable inputs from the foreign country ($\pi^{ms} = 0.3$).[8] At the other extreme, I assume that the tradable sector exports exclusively to the tradable sector. This implies $\pi^{mm} > 0, \pi^{ms} = 0$, and

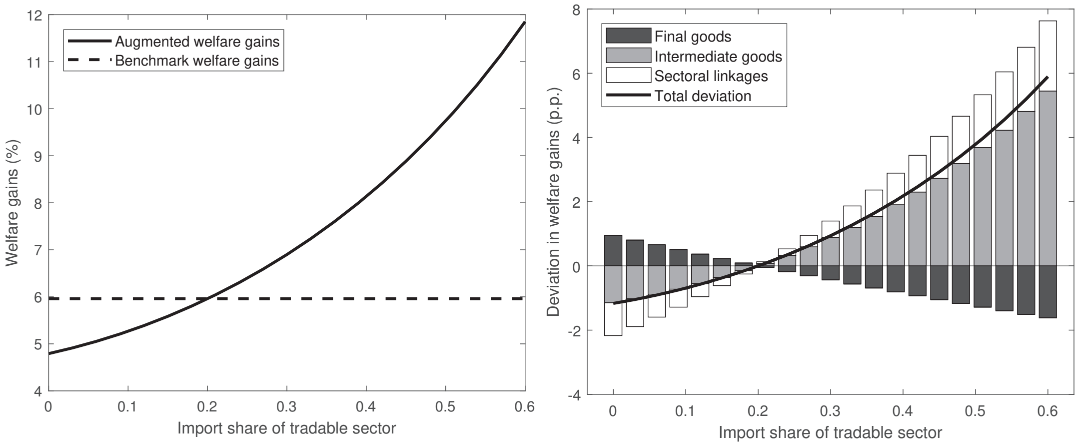
[8] For simplicity, I assume equal total spending by the tradable sector, the non-tradable sector and final consumers on manufacturing goods, and that the tradable sector exports to the foreign consumers and to the foreign non-tradable sector in equal amounts. The import share of final consumers thus always equals the import share by the non-tradable sector.

$\pi^{mf} = 0$. This scenario corresponds to a world, in which the tradable sector buys 60% of its tradable inputs from the foreign country ($\pi^{mm} = 0.6$). In addition, I also solve trade shares for intermediate scenarios between these extremes, in which the tradable sector exports to both tradable and non-tradable foreign sectors. These intermediate scenarios cover $\pi^{mm} \in [0, 0.6]$ and $\pi^{ms} \in [0, 0.3]$. Across all combinations of π^{mm}, π^{ms}, and π^{mf}, the corresponding aggregate import share is constant and equal to the benchmark trade share, $\pi^m = 0.2$.

4.2 Simulations of the toy framework

Within this simple setup, I evaluate how the allocation of imports across sectors shapes the level and decomposition of welfare gains from trade. The simulations focus on the welfare gains from trade, i.e., the percentage change in real wage associated with moving a world without international trade, i.e., in which the underlying trade costs are prohibitively high, to the calibrated equilibrium. I solve for gains from trade in the augmented model under varying allocations of imports and compare them to the welfare gains in the benchmark model. Figure 1 summarizes the main results of the toy model simulations.

Figure 1: Toy framework simulations – country-level results



(a) Welfare gains from trade

(b) Deviation across models

Notes: This figure displays the country-level results of the toy models' simulations. Figure (a) reports the welfare gains (in percent) in the benchmark model (dashed line) and in the augmented model (solid line). Figure (b) reports the deviation (in percentage points) between the augmented and the benchmark welfare gains, as well as the decomposition of this deviation following equation (16).

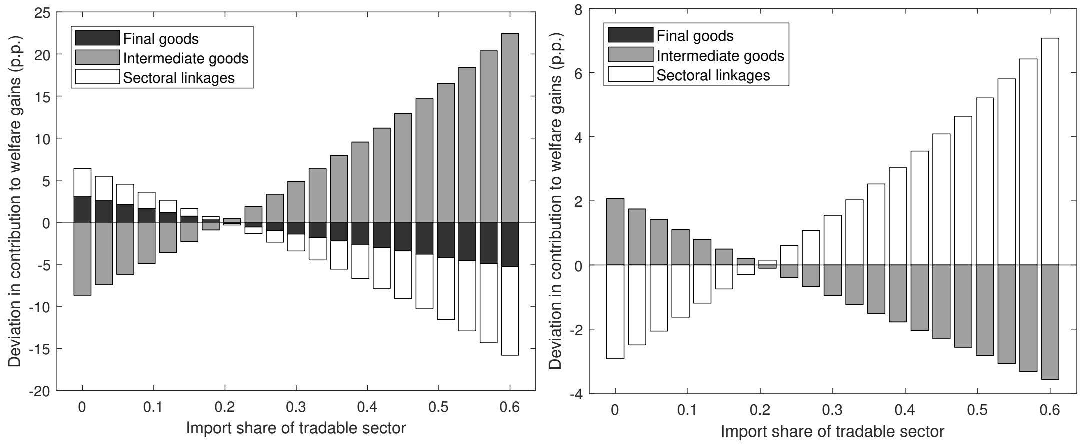
The augmented model does not necessarily predict strictly higher or lower gains from trade compared to the benchmark. Figure 1a reports the level of the augmented gains from trade (solid line) across a range of calibrated import shares of the tradable sector (x-axis) as well as the benchmark gains from trade (dashed line). Unlike benchmark gains from trade, the augmented gains from trade are not constant. For low calibrated values of π^{mm}, the augmented model predicts lower gains from trade than the benchmark model, while for high values of π^{mm}, the augmented model predicts higher gains from trade. All else equal, countries with the same aggregate import share may not have the same welfare gains according to the augmented model if they differ in the way imports are allocated to sectors and final consumers. All else equal, a country in which the tradable sector accounts for most of its imports tends to have higher gains from trade.

Larger augmented welfare gains from trade are driven by the intermediate goods effect and by the sectoral linkages effect. Figure 1b reports the welfare gains deviation (in percentage points) across models and its decomposition into the final goods effect, the intermediate goods effect, and the sectoral linkages effect following equation (16). Positive (negative) values indicate that compared to the benchmark, the augmented model predicts a higher (lower) contribution to gains from trade of each effect. For low values of π^{mm}, the benchmark model overestimates the intermediate goods and sectoral linkages effects, while it underestimates the final goods effect. For high values of π^{mm}, the benchmark model underestimates the intermediate goods and sectoral linkages effects, while it overestimates the final goods effect. Thus as π^{mm} increases, the decline in the final goods effect is more than offset by an increase in the intermediate goods and sectoral linkages effects, which drive larger gains from trade in the augmented model than in the benchmark.

To gain more clarity into those results, it is useful to further decompose the gains from trade by sector. For each sector, Figure 2 reports the deviation (in percentage points) in the sectoral contribution to the aggregate welfare change across models and its decomposition into the final goods effect, intermediate goods effect, and sectoral linkages effect following equation (17). Figure 2 first reports the results for the tradable sector. As π^{mm} increases, the benchmark model underestimates the intermediate goods effect. As the tradable sector accounts for more imports, it directly benefits from more productive goods. This translates into a higher intermediate goods effect in the augmented model. Conversely, as π^{mm} increases, the benchmark model overestimates the final goods effect. As π^{mm} increases, final consumers are allocated less direct imports, which explains a lower final goods effect. As π^{mm} increases, the benchmark model also overestimates the sectoral linkages effect. As π^{mm} increases, the non-tradable sector loses access to productive foreign goods as trade is concentrated within the tradable sector. The lower productivity gains by the non-tradable sector weigh on the productivity of the tradable sector: the sectoral linkages effect becomes less positive (or more negative).

Sector-level results for the non-tradable sector show diametrically op-

Figure 2: Toy framework simulations – sector-level results



(a) Tradable sector

(b) Non-tradable sector

Notes: This figure displays the sector-level results of the toy models' simulations. It reports the deviation (in percentage points) of the sectoral contribution to the aggregate welfare change between the augmented and the benchmark model. The sectoral decomposition of the aggregate welfare change follows equation (17). Figures (a) and (b) show the results for the tradable and non-tradable sector respectively.

posed patterns compared to the tradable sector. As shown in Figure 2b, the intermediate goods effect declines as π^{mm} increases. This is simply because an increase in π^{mm} is associated with a decrease in π^{ms}. The non-tradable sector has less access to direct imports, which limits its productivity gains. As π^{mm} increases, the sectoral linkages effect increases and offsets the decline in the intermediate goods effect.[9] As π^{mm} increases, the benchmark model underestimates the sectoral linkages effect in the non-tradable sector. Although the non-tradable sector is not a large importer, their indirect access to foreign goods through the domestic tradable sector contributes to their own productivity gains. Combining the results of Figure 2 with the aggregate picture of Figure 1, one sees that the intermediate goods effect is dominated by the tradable sector, while the sectoral linkages effect is dominated by the non-tradable sector.

These simulations, although highly stylized, are useful to highlight three patterns of the augmented model compared to the benchmark. First, the augmented model's predictions can be either lower or higher than those of the benchmark. Second, whether they are higher or lower will be strongly influenced by the allocation of imports to the tradable sector. Third, sector-level results are heterogeneous, highlighting the importance of considering sectoral patterns.

[9]The final goods effect is zero since final consumers cannot import directly from the foreign non-tradable sector by assumption.

5 Sectoral import patterns in the data

This section turns to the data and shows how sectors systematically differ in their import behavior. The difficulty in doing so is the lack of data that identify importers within a country in a consistent manner across countries. This section explores two datasets that, despite their respective limitations, are informative about sectoral import patterns across countries: the Asian Input-Output Tables (AIOT) and the World Input-Output Tables (WIOT). This section first describes both databases and the construction of import shares, then highlights three systematic import patterns across sectors.

5.1 Data description

Cross-country trade databases build on disaggregated customs data, which record specific characteristics. Most importantly, a country's customs record the origin of imports and product-specific tariff headings. It is thus straightforward for cross-country databases to publish bilateral trade flows at the product level. For example, researchers know how much Chinese steel is imported by the US. Trade data, however, do not systematically record what kind of importer purchases goods and to what end. If a cross-country database reports imports by sectors, then some underlying assumption is required to allocate imports to agents within an economy. Typically, this assumption is one of proportionality: the same fixed percentage of total use of a product is assumed to be imported, irrespective of its purchaser. For example, if 25% of all US spending on steel is allocated to imports from China, then the proportionality assumption allocates 25% of imports from China to all sectors using steel. The proportionality assumption is consistent with within-country equalized import shares across sectors, which are implicitly assumed in most quantitative Ricardian trade models including Caliendo and Parro (2015). But the proportionality assumption is at odds with the importing sector-specific data needed to calibrate the augmented model. This section presents two datasets which depart from the proportionality assumption and can be used to construct such import shares.

5.1.1 The Asian Input-Output Tables

The first data source is the Asian Input-Output Tables (AIOT). The crucial feature of the AIOT is that sector-to-sector trade flows are constructed based on survey data. The tables thus report how much each sector spends on imported inputs and from where. The AIOT allocate imports to sectors without relying on the proportionality assumption. Thus, sector-specific import shares can be inferred.

The AIOT are published by IDE-JETRO and contain detailed information on trade by end-use for 9 Asian countries plus the US and a constructed rest of the world (ROW). The AIOT report data for 76 sectors, which I classify into 25 sectors following the ISIC revision 3 classification.[10] There are 13 tradable sectors (agriculture plus manufacturing) and 12 non-tradable sectors (services). Data refer to 2005.

The main advantage of the AIOT is that they do not rely on the proportionality assumption. But this approach is costly. The main disadvantage of the AIOT is the low coverage in terms of countries and world GDP. As a means of comparison, I therefore complement the analysis with a more widely used data source that only partially relies on the proportionality assumption, namely the World Input-Output Tables.

5.1.2 The World Input-Output Tables

The World Input-Output Tables (WIOT) provide consistent global input-output tables, which cover a large number of sectors and countries. The WIOT partially rely on the proportionality assumption to allocate imports to sectors and final consumers. But efforts have been made to improve on this assumption. Timmer, Los, Stehrer, and de Vries (2013) explain that imports are allocated to intermediate consumption or to final consumption based on a refinement of the broad economic categories (BEC) codes. Sectoral imports are allocated based on end-use, while the proportionality assumption is applied within an end-use category.

As for the AIOT, I consider data for 2005 and 25 sectors based on the ISIC revision 3 classification. The sample covers 30 countries, which together account for 88% of 2005 world GDP, plus a constructed rest of the world (ROW).[11]

As the WIOT are more commonly used in the literature and cover a large number of advanced economies, the WIOT provide a useful comparison to the AIOT despite limitations in terms of methodology.

5.2 Constructing the import shares

Based on the AIOT and WIOT, I construct sector-specific import shares that are consistent with the augmented model. I compare them to benchmark trade shares, which are consistent with the Caliendo and Parro (2015) model.

[10] Appendix C examines the AIOT in more details. Table 6 reports a description of the sectors and concordance to the ISIC classification. Asian countries of the AIOT sample are: China, Thailand, Taiwan, Malaysia, Singapore, Korea, Indonesia, the Philippines, and Japan.

[11] The countries are: Australia, Austria, Belgium, Brazil, Canada, the Czech Republic, Germany, Denmark, Spain, Finland, France, the UK, Greece, Hungary, India, Ireland, Italy, Mexico, the Netherlands, Poland, Portugal, Russia, Sweden, and Turkey plus a composite rest of the world (ROW).

Sector-specific import shares are given by

$$\pi_{in}^{sb} = \frac{X_{in}^{sb}}{X_n^{sb}}, \tag{21}$$

where i and n index the exporting and importing countries respectively, $s = 1, \ldots, S$ and $b = 1, \ldots, S+1$ index the exporting and importing sectors respectively, X_{in}^{sb} is the trade value between sector s of country i and sector b of country n, and $X_n^{sb} = \sum_{i=1}^{N} X_{in}^{sb}$ is the total spending of sector b in country n on goods from sector s. Note that I construct such trade shares for all importing sectors plus final demand.

Benchmark trade shares are given by

$$\pi_{in}^{s} = \frac{X_{in}^{s}}{X_n^{s}} = \frac{\sum_{b=1}^{S+1} X_{in}^{sb}}{\sum_{b=1}^{S+1} X_n^{sb}}, \tag{22}$$

where X_{in}^{s} are total imports from sector s in country i by country n and X_n^s is total spending on goods from sector s in country n. This trade share is applied to all importing agents b, i.e., $\pi_{in}^{sb} = \pi_{in}^{s}\ \forall b$ and is thus consistent with the proportionality assumption.

For the rest of this paper, I denote as augmented the trade shares which vary across importing agents (following equation (21) without the proportionality assumption) and as benchmark the trade shares which are equalized across importing agents within a country (following equation (22) with the proportionality assumption).

5.3 Three sectoral import patterns

Having described the data sources, I now highlight three regularities that reveal systematic differences between the augmented and benchmark trade shares. Compared to augmented trade shares, benchmark trade shares (1) overestimate the extensive margin of sectoral imports and (2) underestimate the intensive margin of the largest importers (in terms of country-level import value). Finally, the augmented trade shares show that (3) sectors with the highest import intensity also have the highest export intensity.

5.3.1 Extensive margin of sectoral imports

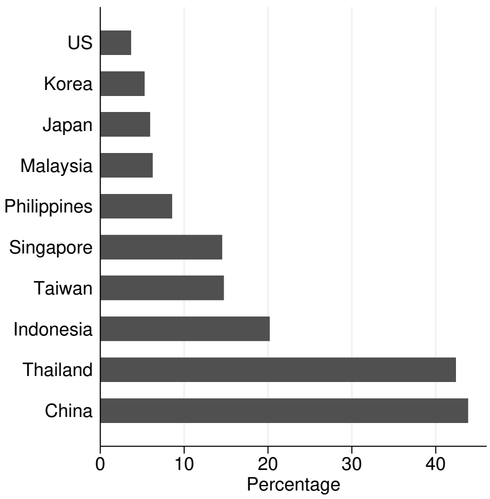
Relying on benchmark trade shares overestimates the extensive margin of sectoral imports. For each data source, I calculate the occurrence of zero augmented and benchmark trade shares, i.e., $\pi_{in}^{sb} = 0$ or $\pi_{in}^{s} = 0$ for all $i \neq n$.[12] Looking at the benchmark trade shares, there are no zeros in the

[12] I omit zero trade shares if the corresponding input-output linkages are zero, $\pi_{in}^{sb} = 0$ or $\pi_{in}^{s} = 0$ and $\rho^{sb} = 0$. I further omit data where ROW is an importer because such data is not survey-based.

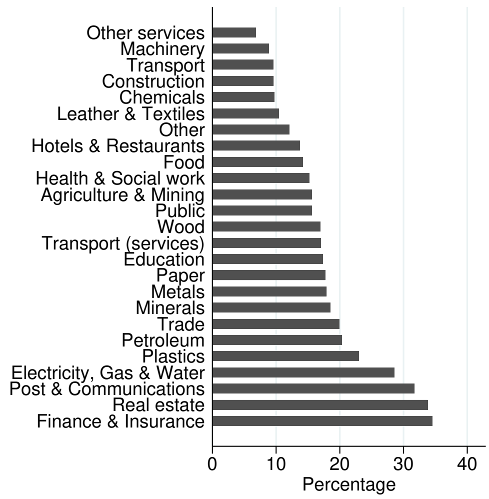
data. In contrast, augmented trade shares may be zero.

The occurrence of zero augmented trade shares depends on the importing country and the importing sector. Figure 3a shows the share of zero trade relationships ($\pi_{in}^{sb} = 0$) per importing country. In the average importing country, 17% of augmented trade shares are zeros based on the AIOT. The number of zero augmented trade shares varies largely at the country level, from less than 4% in the US to 44% in China. As shown in Figure 3b, the occurrence of zero augmented trade shares also varies significantly across importing sectors. A low occurrence of zero augmented trade shares is concentrated among manufacturing sectors (machinery, transport equipment, chemicals). A high occurrence of zero augmented trade shares tends to be concentrated among non-tradable services sectors (post and telecommunication, real estate, finance and insurance).

Figure 3: Zero trade in the AIOT



(a) By importing country



(b) By importing sector

Notes: This figure displays the percentage of zero trade shares in the AIOT following equation (21), i.e., $\pi_{in}^{sb} = 0$ for any $i \neq n$, per (a) importing country and (b) importing sector. Trade shares, in which the rest of the world (ROW) is the importer, are excluded. Trade shares in which the corresponding input-output linkages are zero ($\pi_{in}^{sb} = 0$ or $\pi_{in}^{s} = 0$ and $\rho^{sb} = 0$) are also excluded.
Sources: 2005 AIOT.

Equalizing import shares across sectors within an economy thus assigns positive trade to sectors that in fact do not import from given sectors or countries. This first fact follows from the aggregation level underlying each set of trade shares. But it is still an important feature of the data as trade flows are misallocated under the benchmark approach. Note that the occurrence of zero trade shares is specific to the AIOT. In contrast, the WIOT report around 1% of zero augmented trade shares in its sample. This feature may be rationalized by the data construction's methodology and by the sample which covers advanced economies that are significantly involved in world trade.[13]

5.3.2 Intensive margin of sectoral imports

Relying on benchmark trade shares underestimates the intensive margin of the largest importers (in terms of country-level import value). I evaluate the link between the size of a sector and its import share from a trading partner. Let the size of sector b as an importer be captured by the share of sector b in country n's total imports from sector s of country i. Formally, the size of sector b in country n vis-à-vis exporting sector s in country i is

$$w_{in}^{sb} = \frac{X_{in}^{sb}}{\sum_b^{S+1} X_{in}^{sb}}. \tag{23}$$

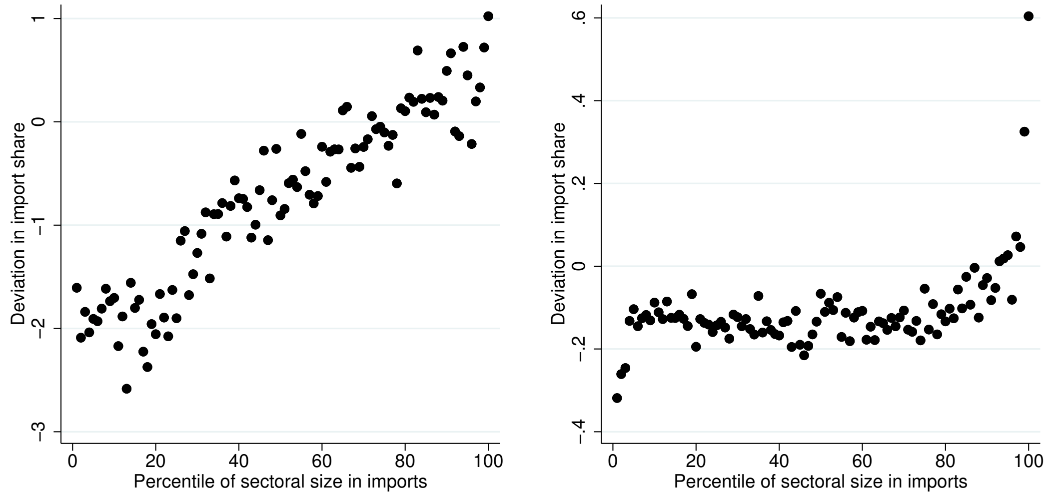
Figure 4 reports the average deviation between the augmented and benchmark import shares in each percentile of the sectoral size distribution as defined in equation (23). Negative (positive) deviations imply that the benchmark import shares overestimate (underestimate) the intensive margin of sectoral imports.

Benchmark trade shares systematically underestimate the import shares of those sectors which account for most of a country's imports. This pattern is especially strong in the AIOT as shown in Figure 4a. Among the sectors with the bottom 25 percent import sizes, augmented trade shares are around 2 percentage points lower than the benchmark trade shares. Among the sectors with the top 25 percent import sizes, augmented trade shares are around 0.4 percentage point higher than the benchmark trade shares. This pattern is still present but weaker in the WIOT as shown in Figure 4b. Among the sectors with the bottom 25 percent import sizes, augmented trade shares are around 0.1 percentage point lower than the benchmark trade shares. Among the sectors with the top 25 percent import sizes, augmented trade shares are around 0.1 percentage point higher than the benchmark trade shares.

This pattern may seem trivial, but it contradicts the proportionality assumption, in that one should find no systematic relationship between how much a sector imports from a trading partner and its import share from that trading partner. This pattern holds both in the AIOT and WIOT. Although the WIOT partly rely upon the proportionality assumption, accounting for the importing sector margin still reveals systematic import patterns across sectors.

[13] There is, however, some variation across countries and sectors. Figure 7 in Appendix C reports the results for the WIOT.

Figure 4: Intensive margin of sectoral imports



(a) AIOT (b) WIOT

Notes: This figure reports the average deviation between the augmented and benchmark import shares per percentile of the sectoral import size distribution across countries and sectors. Augmented import shares π_{in}^{sb} are defined in equation (21). Benchmark import shares π_{in}^{s} are defined in equation (22). Trade shares, in which the rest of the world (ROW) is the importer, are excluded. Trade shares, in which the corresponding input-output linkages are zero ($\pi_{in}^{sb} = 0$ or $\pi_{in}^{s} = 0$ and $\rho^{sb} = 0$), are also excluded. The sectoral import size is defined in equation (23).
Sources: 2005 AIOT, 2005 WIOT.

5.3.3 Link to export behavior

Sectors with the highest import intensity also have the highest export intensity. I evaluate the link between sector-level exporting and importing intensities. Formally, let the export intensity of a sector in country i be defined by the ratio of exports to production, weighted by the destination sector:

$$x_i^s = \sum_{b=1}^{S+1} \omega_i^{sb} \Big[\frac{\sum_{n,n\neq i} X_{in}^{sb}}{\sum_n X_{in}^{sb}} \Big], \tag{24}$$

where ω_i^{sb} is the share of exports to sector b

$$\omega_i^{sb} = \frac{\sum_{n,n\neq i} X_{in}^{sb}}{\sum_{b=1}^{S+1} \sum_{n,n\neq i} X_{in}^{sb}}.$$

Let the import intensity of sector b in country n be defined by the ratio of total imports to total spending, weighted by the origin sector:

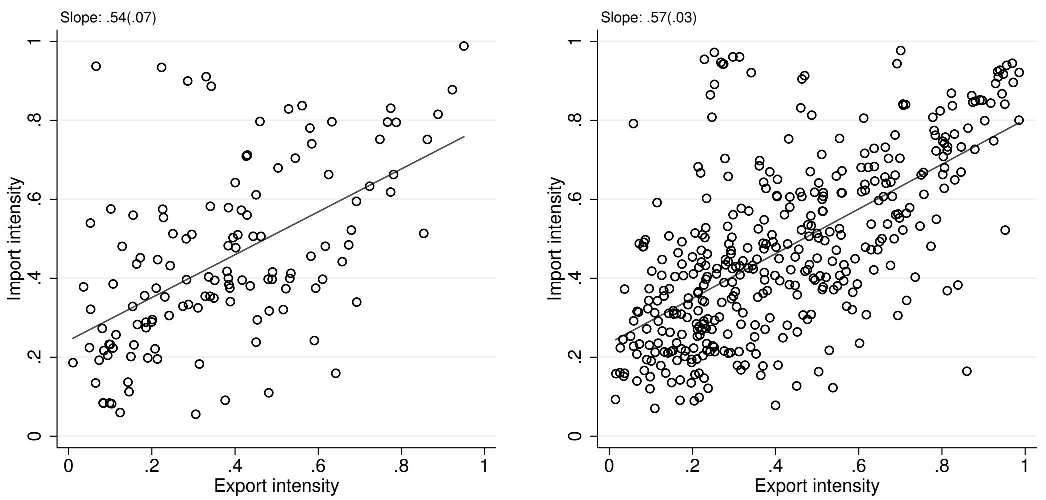
$$m_n^b = \sum_s \psi_n^{sb} \Big[\frac{\sum_{i,n \neq i} X_{in}^{sb}}{\sum_i X_{in}^{sb}} \Big], \tag{25}$$

where ψ_n^{sb} is the share of sector s in total imports by sector b

$$\psi_n^{sb} = \frac{\sum_{i,n \neq i} X_{in}^{sb}}{\sum_s \sum_{i,n \neq i} X_{in}^{sb}}.$$

As shown in Figure 5, there is a significant positive correlation between sector-specific import and export intensities based on the AIOT and WIOT. Based on the AIOT, sectors at the top 10 percent in terms of export intensity have a 2.4 higher import intensity than those at the bottom 10 percent, while sectors at the top 25 percent in terms of export intensity have a 2.1 higher import intensity than those at the bottom 25 percent. This pattern is similar based on the WIOT. Sectors at the top 10 percent in terms of export intensity have a 2.6 higher import intensity than those at the bottom 10 percent, while sectors at the top 25 percent in terms of export intensity have a 2.3 higher import intensity than those at the bottom 25 percent.

Figure 5: Sectoral import and export intensity



(a) AIOT

(b) WIOT

Notes: The figure reports the correlation between sectoral import and export intensities. Figures (a) and (b) report the results based on the AIOT and the WIOT respectively. On the x-axis, I plot the export intensity of a sector defined as x_i^s in equation (24) and on the y-axis the importer intensity defined as m_i^s in equation (25). The best linear fit between both measures is reported.
Sources: 2005 AIOT, 2005 WIOT.

Again, this pattern may seem trivial, but it may have important implications for the magnitude of gains from trade. As shown in the toy model, augmented welfare gains from trade tend to be higher when trade is concentrated in the tradable sector.

6 Quantifying the impact of sectoral import behavior

I now bring the augmented and benchmark models to the data and present the results of the main counterfactual exercise. This section first describes the quantification of the models, then examines how accounting for import patterns across sectors affects the magnitude of welfare gains from trade compared to the benchmark Ricardian trade model of Caliendo and Parro (2015).

6.1 Calibrating the models to cross-country data

The main results draw on two calibrations set to 2005 data: the first is based on the AIOT, the second on the WIOT. Both calibrations follow a similar approach. Table 2 summarizes their main features.[14] The AIOT calibration covers 9 Asian countries plus the US and a constructed rest of the world (ROW). The WIOT calibration covers 30 countries plus ROW. Six countries (Japan, Korea, China, Indonesia, Taiwan, and the US) are included in both samples. Both calibrations cover 25 sectors based on the ISIC revision 3 classification, among which 13 sectors are tradable (agriculture, mining and manufacturing) and 12 are non-tradable (services). Within each calibration, I quantify the augmented and benchmark models.

Using the "exact-hat algebra" approach greatly simplifies the calibration in terms of identification and data requirements. The equilibrium resulting from a change in fundamentals, e.g., trade costs, can be solved with calibrated production and consumption function parameters, data on initial trade shares and estimates of trade elasticities.

Within each calibration (either based on the AIOT or WIOT), consumer preferences and production function parameters are common to the augmented and benchmark models. Sectoral shares in final consumption β^s are calibrated to their directly observable counterpart in the AIOT and WIOT. On average, consumers spend 31% of their total income on tradable goods in the AIOT and 25% in the WIOT. This is in line with the preferred value of 0.25 in Alvarez and Lucas (2007). Services thus account for approximately 70% of total consumer spending. Sectoral value added shares α^s are calibrated to the ratio of value added to gross production. The average value added share in tradable sectors is 0.32 in the AIOT and 0.33 in the

[14] Table 7 in Appendix C reports the calibrated values of sector-specific parameters.

Table 2: Calibration to cross-country data

Calibrated parameters	AIOT	WIOT
Countries N	11	31
Sectors S	25	25
Tradable sectors	13	13
Consumer spending on tradable goods (%)	31	25
Average value added share of tradable sectors	0.32	0.33
Average value added share of non-tradable sectors	0.56	0.59

Notes: This table reports the main features of the calibration of the benchmark and augmented models to cross-country data. Table 7 in Appendix C reports the values of sector-specific parameters.
Sources: 2005 AIOT, 2005 WIOT.

WIOT. This is in line with the literature. For example, Eaton, Kortum, and Kramarz (2011) set the labor share in manufacturing to 0.34. In contrast to the tradable sectors, the non-tradable sectors exhibit larger value added shares. The average value added in non-tradable sectors is 0.56 in the AIOT and 0.59 in the WIOT. Input-output linkages ρ^{sb} are matched to the share of sector s in total inputs used by sector b as observed in the AIOT and WIOT.[15]

Within each calibration (either based on the AIOT or WIOT), the models only differ in their import shares. For each calibration, the augmented model's trade shares π_{in}^{sb} are those of equation (21). The benchmark model's trade shares are those of equation (22). The construction and characteristics underlying each set of trade shares are given in Section 5.

Sectoral trade elasticities θ^s are taken from Caliendo and Parro (2015). Most of the sectors can be matched to a single elasticity in the Caliendo and Parro (2015) framework. If a sector matches to more than one trade elasticity, I take the average.[16] Caliendo and Parro (2015) further assume a trade elasticity of 5 for all non-tradable sectors. I follow their approach in this regard. The sectoral elasticities range from 1.1 in the transport manufacturing sector to 64.8 in the petroleum sector.

Given these values, I calibrate the initial levels of labor income I_i and sectoral production Y_i^s that solve the equilibrium conditions of equations (9) and (10). Doing so imposes balanced trade on the data. Appendix B presents the algorithm to solve the model numerically, which closely follows

[15] I assume that consumer spending shares β^s, value added shares α^s and input-output linkages ρ^{sb} do not vary across countries as most of the variation in these parameters is explained by sectors rather than countries. This assumption is consistent with the approach in Eaton and Kortum (2002), Tombe (2015), and Alvarez and Lucas (2007).

[16] Table 6 reports the concordance to the Caliendo and Parro (2015) framework.

that of Caliendo and Parro (2015).

6.2 Cross-country counterfactual analysis

The counterfactual analysis evaluates the welfare gains from trade, i.e., the percentage change in real wage associated with moving from a world without international trade (where $\kappa_{in}^{sb} = \infty$ or $\kappa_{in}^{s} = \infty$ for all $n \neq i$) to the observed equilibrium. As described in the previous section, I rely on two separate calibrations: one based on the AIOT, the other on the WIOT. Within each calibration, I compare the augmented model's predictions to those of the benchmark model using equation (16). This section mainly focuses on the AIOT calibration, while providing the results of the WIOT calibration for countries included in both samples as comparison.[17]

6.2.1 Country-level results

Under both calibrations, the benchmark model consistently underestimates the welfare gains from trade in all sample countries. Columns (1) to (3) of Table 3 report the welfare gains from trade in the AIOT calibration. Overall, the welfare gains from trade predicted by both models are close. On average, welfare gains from trade are 14.5% in the augmented and 12.4% in the benchmark model.[18] Nevertheless, the benchmark's welfare gains from trade are lower than those of augmented model in all countries. The average underestimation of gains from trade is 23.5%. Compared to the augmented model, the benchmark model predicts between 1.7% and 66% lower welfare gains in the US and Japan respectively.

As for the AIOT calibration, the benchmark model consistently underestimates the welfare gains from trade in all sample countries under the WIOT calibration. Columns (4) to (6) of Table 3 report the results for the WIOT calibration. On average, the predictions of the benchmark and augmented models are relatively close. But welfare gains from trade are on average 13.4% lower in the benchmark compared to the augmented model. Compared to the augmented model, the benchmark model predicts 1.6% and 19% lower welfare gains in the US and Japan respectively, but up to 81.3% in Indonesia.

The benchmark model predicts similar magnitudes of welfare gains from trade for countries that are available in both calibrations. Across calibrations, the average (absolute) discrepancy in the benchmark welfare gains from trade is 1.7 percentage points. In contrast, the average discrepancy in the augmented welfare gains from trade across calibrations is 3 percentage points. Thus, the benchmark approach yields consistent results across

[17] Full results of the WIOT sample are reported in Appendix D.

[18] I do not consider the results for ROW as the AIOT do not construct ROW with survey data. Averages therefore do not include ROW.

Table 3: Welfare gains from trade under autarky

	AIOT			WIOT		
	Augmented	Benchmark	Deviation (%)	Augmented	Benchmark	Deviation (%)
Country	(1)	(2)	(3)	(4)	(5)	(6)
China	6.1	4.3	41.5	3.4	3.2	7.8
Indonesia	10.3	7.7	34.6	16.1	8.9	81.3
Japan	7.7	4.6	66.0	3.7	3.1	19.0
Korea	9.0	7.1	27.6	6.7	4.5	49.5
Malaysia	16.1	15.3	5.7	.	.	.
Philippines	17.3	15.6	11.0	.	.	.
Singapore	34.8	31.4	10.8	.	.	.
Thailand	19.3	15.9	21.2	.	.	.
Taiwan	16.0	14.0	14.6	14.4	11.7	23.5
US	7.9	7.7	1.7	6.2	6.1	1.6
Average	14.5	12.4	23.5	16.3	14.7	13.4

Notes: This table reports the augmented and benchmark welfare gains from trade. Columns (1) to (3) pertain to the AIOT calibration. Columns (4) to (6) pertain to the WIOT calibration. Columns (1) and (4) report the welfare gains from trade in the augmented model, i.e., the absolute percentage change in real income associated with moving from a world without international trade, i.e., $\kappa_{in}^{sb} = \infty$ for all $i \neq n$, to the observed equilibrium. Columns (2) and (5) report the welfare gains from trade under the benchmark model of Caliendo and Parro (2015). Columns (3) and (6) report by how much, in percent, the prediction of the augmented model deviates from the benchmark model. Missing values indicate that the countries are not covered by the WIOT sample. Full results for the WIOT sample are reported in Table 9 of Appendix D. Averages include all countries in the AIOT and in the WIOT sample respectively except for ROW.

calibrations, although the AIOT and WIOT are constructed using different data sources and methodologies. This feature is reassuring in terms of data quality and the results' robustness. Most of the deviation in welfare gains from trade across calibrations stems from the augmented model, implying that the results are quite sensitive to the allocation of imports across sectors and the underlying data construction methodology.

Decomposing welfare gains from trade helps understand the drivers of their systematic underestimation by the benchmark model. Table 4 reports the deviation (in percentage points) in the predicted gains from trade between the augmented model and the benchmark model. It further decomposes this deviation into the final goods effect, the intermediate goods effect, and the sectoral linkages effect following equation (16). Positive numbers indicate a larger (or a less negative) effect in the augmented model, while negative numbers indicate a smaller effect in the augmented model.

The results suggest no strong systematic pattern in the contribution of each effect at the country level. Columns (1) to (4) report the AIOT calibration's results. On average, the total deviation in welfare gains from trade is 2.1 percentage points. Half of this deviation is explained by deviations in trade shares (intermediate and final goods effects). The other half of the average deviation is explained by the sectoral linkages effect. Although on average all three effects contribute positively to the total deviation, the deviation in these effects may be negative or positive at the country level.

The WIOT results' decomposition is broadly in line with the AIOT cal-

Table 4: Deviation between augmented and benchmark welfare gains

	AIOT				WIOT			
	Total	Final goods	Intermediate goods	Sectoral linkages	Total	Final goods	Intermediate goods	Sectoral linkages
Country	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
China	1.8	0.2	0.4	1.3	0.2	0.2	-0.1	0.1
Indonesia	2.7	-0.4	2.1	1.0	7.2	-0.4	13.3	-7.5
Japan	3.1	0.1	1.0	2.1	0.6	0.7	-0.5	0.5
Korea	2.0	-0.3	0.7	1.7	2.2	0.9	0.9	0.5
Malaysia	0.9	1.1	0.9	-1.2	.	.	.	.
Philippines	1.7	-0.6	1.1	1.5	.	.	.	.
Singapore	3.4	4.8	-1.9	2.4	.	.	.	.
Thailand	3.4	0.4	3.4	-0.4	.	.	.	.
Taiwan	2.0	-0.2	-0.2	2.9	2.7	0.6	3.3	-1.2
US	0.1	0.3	-0.5	0.4	0.1	0.4	-0.9	0.6
Average	2.1	0.5	0.7	1.2	1.7	0.8	0.7	0.3

Notes: This table reports the deviation between augmented and benchmark welfare gains across countries, and its decomposition. Columns (1) to (4) pertain to the AIOT calibration. Columns (5) to (8) pertain to the WIOT calibration. Columns (1) and (5) report the deviation in percentage points between the gains from trade predicted by the augmented model and by the benchmark model of Caliendo and Parro (2015). Columns (2) to (4) and (6) to (8) report the decomposition of the deviation in gains from trade into the final goods effect, the intermediate goods effect, and the sectoral linkages effect following equation (16). Full results for the WIOT sample are reported in Table 10 in Appendix D. Averages include all countries in the AIOT and in the WIOT sample respectively but for ROW.

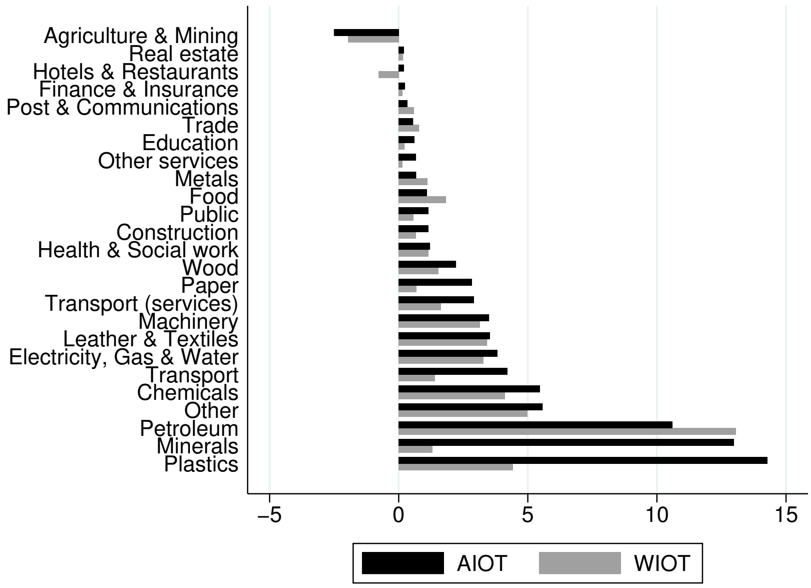
ibration. Columns (5) to (8) report the WIOT calibration's results. On average, the total deviation in welfare gains from trade is 1.7 percentage points. All three effects contribute to the average deviation, but most of the deviation is explained by trade share deviations (final and intermediate goods effects). The sectoral linkages effect contributes to around a fifth of the total average deviation. Unlike the AIOT calibration, the final goods effect tends to be stronger under the augmented model. This pattern may reflect the methodology underlying the WIOT. As mentioned in the previous section, the WIOT rely on the BEC classification to assign imports to final consumers. Overall, the WIOT allocate a greater share of trade to final consumers than the AIOT. The augmented model predicts that almost half of the total welfare gains from trade can be attributed to final goods trade under the WIOT calibration, but only a third under the AIOT calibration.

At the country level, no effect clearly emerges as the driver of higher welfare gains from trade in the augmented model. On average, all three effects contribute to larger gains from trade, but there is significant heterogeneity across countries.

6.2.2 Sector-level results

The sectoral analysis sheds more light on the underestimation of welfare gains from trade by the benchmark model. I calculate the deviation in percentage points of the sectoral contribution to gains from trade, as in equation (17), between the augmented model and the benchmark model. Figure 6 shows the average deviation in the sectoral contributions to gains from trade across sample countries under each calibration. A positive number indicates that a sector contributes more to gains from trade under the augmented model compared to the benchmark model, while a negative number indicates a smaller contribution.[19]

Figure 6: Deviation (in pp) between augmented and benchmark sectoral contributions to aggregate welfare gains



Notes: This figure displays the average deviation (in percentage points, pp) between the augmented and benchmark sectoral contributions to the country-level welfare change, as given by equation (17). Detailed results at the country level for both calibrations are reported in Tables 11, 12, and 13 in Appendix D.

Most sectors contribute to the higher aggregate welfare gains predicted by the augmented model. As shown in Figure 6, most sector-level deviations are on average positive in both calibrations. There is one exception: the agriculture and mining sector contributes less to the gains from trade in the augmented model. Nevertheless, there is considerable heterogeneity in the results across sectors and across calibrations. For example, the contribution of the plastics, minerals, and petroleum industries tends to be significantly higher, e.g., on average 10 percentage points higher based on the AIOT, in the augmented model. Figure 6 further shows that across calibrations, the deviations in the sectoral contributions to gains from trade

[19]The detailed country-level results for the AIOT and WIOT calibrations are reported in Tables 11 and 12 in the Appendix.

are broadly consistent. Discrepancies may be explained by the sample and the methodology underlying the data.

Although all sectors tend to contribute to the larger aggregate welfare gains in the augmented model, sectors with high import intensity contribute to welfare gains the most. To show this, Table 5 reports the average deviation in the sectoral contribution to aggregate welfare gains in specific percentiles of the sectoral import intensity distribution, as defined in equation (25), across sectors and countries. Based on the AIOT results, sectors with a higher import intensity exhibit larger contributions to aggregate welfare gains. Sectors at the bottom 10 and 25 percentiles of the import intensity distribution have on average 0.5 and 1.4 percentage points higher contributions in the augmented model compared to the benchmark model. In contrast, sectors in the middle 50 percentiles have on average 3.2 percentage points higher contributions. Finally, sectors at the top 25 and 10 percentiles of the import intensity distribution have on average 4.5 and 6.2 percentage points higher contributions.

The total deviation can be decomposed into the intermediate goods effect and the sectoral linkages effect. The intermediate goods effect drives higher productivity gains in sectors with a high import intensity. The benchmark model tends to underestimate the extent at which these sectors' direct access to productive, cheap inputs drives welfare gains. Conversely, the benchmark model overestimates the sectoral linkages effect in sectors with a high import intensity. In the augmented model, linkages to other, overall less productive sectors tend to weigh on those sectors with high import intensity. The opposite holds in sectors with a low import intensity. The results show that the indirect access to foreign cheap inputs through sectoral linkages drives higher productivity gains in sectors with a low import intensity. Results for the WIOT calibration show similar patterns.

Sector-level results are heterogeneous and might offset each other. Thus, considering results at the sector level is important to nuance the country-level results. Trade is concentrated among the largest, most open trading sectors in the augmented calibration. Although gains from trade are higher at the country level, the largest trading sectors gain the most, while small trading sectors exhibit lower gains from trade. Sectors with lower exposure to foreign markets may still contribute to higher welfare gains through larger sectoral linkages effects. These patterns are similar to those illustrated in the simple two-sector two-country toy framework, although the complexity of countries' trade and production patterns does not permit to draw stark predictions at the country level.

Table 5: Import intensity and sectoral contribution to the country-level welfare change

	Percentiles of sectoral import intensity				
	Bottom	Bottom	Middle	Top	Top
Panel A: AIOT	10	25	50	25	10
Total deviation (pp)	0.5	1.4	3.2	4.5	6.2
Intermediate goods (pp)	-1.5	-1.6	0.9	5.8	9.6
Sectoral linkages (pp)	2.7	2.7	1.1	-3.6	-6.7

	Percentiles of sectoral import intensity				
	Bottom	Bottom	Middle	Top	Top
Panel B: WIOT	10	25	50	25	10
Total deviation (pp)	1.1	1.0	1.3	4.0	7.9
Intermediate goods (pp)	-0.9	-1.1	-0.3	5.8	12.8
Sectoral linkages (pp)	0.9	1.1	1.3	-29.8	-76.2

Notes: The table shows the deviation, in percentage points (pp), between the augmented and benchmark sectoral contributions to aggregate welfare gains per percentile groups of observed sectoral import intensities across countries and sectors. Import intensity is defined in equation (25). The sectoral contribution to the country-level welfare change is given by equation (17). The total deviation, as well as its decomposition into the intermediate goods effect and the sectoral linkages effect, are reported. Groups refer the bottom 10 percent, the bottom 25 percent, the middle 50 percent, the top 25, and the top 10 percent of the import intensity distribution across countries. The reported deviation in welfare gains is the average per group. Panel A refers to the AIOT calibration and Panel B to the WIOT calibration.

7 Conclusion

This paper proposes a multi-country multi-sector general equilibrium Ricardian international trade model, which includes within-country variation in trade shares across importing sectors. Counterfactual analysis evaluates the welfare gains from trade and compares them to the benchmark approach of Caliendo and Parro (2015). Counterfactual analysis shows that based on two calibrations using cross-country data, the benchmark model underestimates welfare gains from trade by 13 to 24% on average compared to the augmented model. The benchmark model is shown to underestimate the productivity gains of sectors which account for most country-level imports through their access to foreign cheap inputs, and the spillovers of their productivity gains on other sectors through sectoral linkages.

This paper provides the first general equilibrium analysis accounting for variation in import shares at the sector level, and thus it offers a first step towards understanding how gains from trade are distributed within the importing economy. Countries seem, on average, to benefit more from trade than benchmark models would have predicted, whereas sectors do not necessarily. This paper highlights the need for better data on the import side and further research on import patterns at the sector level.

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A Theory appendix

A.1 Additional derivations of the augmented model

Price index: I derive the price of the composite good supplied by sector s to buyers b in country n as seen in equation (7). Given that markets are perfectly competitive, prices equal costs. The price of good ω produced in country i and sector s for sector b in country n is

$$p_{in}^{sb}(\omega) = \frac{\kappa_{in}^{sb} c_i^s}{z_i^s(\omega)}.$$

Given that the productivity of sector s in country i for the production of good ω, $z_i^s(\omega)$, is given by equation (4), the probability distribution of prices for goods supplied by country i's sector s to country n is given by

$$G_{in}^{sb}(p) = \Pr[p_{in}^{sb} \leq p] = 1 - \exp(-\Phi_{in}^{sb} p^{\theta^s})$$

where $\Phi_{in}^{sb} = T_i^s(\kappa_{in}^{sb} c_i^s)^{-\theta^s}$. Assuming that draws from the Fréchet distribution are independent across countries and goods, the distribution of the lowest price for goods of sector s available in country n is derived as

$$\begin{aligned}
G_n^{sb}(p) &= \Pr[p_n^{sb} < p] \\
&= 1 - \Pr[p_{in}^{sb} > p \forall i] \\
&= 1 - \prod_{i=1}^{N} \Pr[p_{in}^{sb} > p] \\
&= 1 - \prod_{i=1}^{N} [1 - \Pr[p_{in}^{sb} \leq p]] \\
&= 1 - \prod_{i=1}^{N} \exp(-\Phi_{in}^{sb} p^{\theta^s})] \\
&= 1 - \exp(-\Phi_n^{sb} p^{\theta^s}),
\end{aligned} \tag{26}$$

where $\Phi_n^{sb} = \sum_{i=1}^{N} \Phi_{in}^{sb}$. Given the CES inner tier of the consumer preferences and production function, one can finally derive:

$$\begin{aligned}
\left(P_n^{sb}\right)^{1-\sigma^s} &= \int_0^1 p_n^{sb}(\omega)^{1-\sigma^s} d\omega \\
&= \int_0^\infty p^{1-\sigma^s} \theta^s \Phi_n^{sb} p^{\theta^s - 1} \exp(-\Phi_n^{sb} p^{\theta^s}) dp \\
&= \Gamma\Big(\frac{\theta^s + 1 - \sigma^s}{\theta^s}\Big)\left(\Phi_n^{sb}\right)^{-\frac{1-\sigma^s}{\theta^s}},
\end{aligned}$$

using the corresponding density function of equation (26), the change of variable $x = \Phi_n^{sb} p^{\theta^s}$ and the gamma function, $\Gamma(t) = \int_0^\infty x^{t-1} \exp(-x) dx$.

Trade share: Let X_{in}^{sb} be the spending of sector b in country n on goods of sector s from country i, and $X_n^{sb} = \sum_i X_{in}^{sb}$. Then the trade share $\pi_{in}^{sb} = \frac{X_{in}^{sb}}{X_n^{sb}}$ is simply the probability that country i offers the lowest price. Formally,

$$\begin{aligned}
\pi_{in}^{sb} &= \Pr[p_{in}^{sb} < \min_{k \neq i} p_{kn}^{sb}] \\
&= \int_0^\infty \prod_{k \neq i} \Big(1 - G_{kn}^{sb}(p)\Big) dG_{in}^{sb} \\
&= \frac{\Phi_{in}^{sb}}{\Phi_n^{sb}}
\end{aligned}$$

Welfare equation: I derive equation (16) using equation (12) and (13).

$$\begin{aligned}
\frac{\hat{w}_n}{\hat{P}_n} &= \hat{w}_n \Big(\prod_{s=1}^{S} (\hat{P}_n^{sf})^{\beta^s} \Big)^{-1} \\
&= \prod_{s=1}^{S} \hat{w}_n^{\beta^s} (\hat{P}_n^{sf})^{-\beta^s} \\
&= \prod_{s=1}^{S} \hat{w}_n^{\beta^s} \Big(\frac{\hat{w}_n^{\alpha^s} (\prod_{k=1}^{K} (\hat{P}^{ks})^{\rho^{ks}})^{1-\alpha^s}}{(\hat{\pi}_{nn}^{sf})^{-\frac{1}{\theta^j}}} \Big)^{-\beta^s} \\
&= \prod_{s=1}^{S} \hat{w}_n^{\beta^s(1-\alpha^s)} (\hat{\pi}_{nn}^{sf})^{-\frac{\beta^s}{\theta^s}} \Big[\prod_{k=1}^{S} (\hat{P}_n^{ks})^{\rho^{ks}} \Big]^{-\beta^s(1-\alpha^s)} \\
&= \prod_{s=1}^{S} (\hat{\pi}_{nn}^{sf})^{-\frac{\beta^s}{\theta^s}} \Big[\prod_{s=1}^{S} \prod_{k=1}^{S} \Big(\frac{\hat{P}_n^{ks}}{\hat{w}_n}\Big)^{\rho^{ks}} \Big]^{-\beta^s(1-\alpha^s)} \\
&= \prod_{s=1}^{S} (\hat{\pi}_{nn}^{sf})^{-\frac{\beta^s}{\theta^s}} \Big\{ \prod_{s=1}^{S} \prod_{k=1}^{S} (\hat{P}_n^{ks})^{\rho^{ks}} \Big[\frac{\Big(\prod_j \hat{P}_n^{jk\rho^{jk}} \Big]^{\frac{1-\alpha^k}{\alpha^k}}}{\Big(\hat{P}_n^{ks} \hat{\pi}_{nn}^{ks^{-1/\theta^k}} \Big)^{1/\alpha^k}} \Big)^{\rho^{ks}} \Big\}^{-\beta^s(1-\alpha^s)} \\
&= \prod_{s=1}^{S} (\hat{\pi}_{nn}^{sf})^{-\frac{\beta^s}{\theta^s}} \Big[\prod_{s=1}^{S} \prod_{k=1}^{S} (\hat{\pi}_{nn}^{ks})^{-\frac{\rho^{ks}}{\alpha^k \theta^k}} \Big]^{\beta^s(1-\alpha^s)} \prod_{s=1}^{S} \prod_{k=1}^{S} \prod_{j=1}^{S} \Big[\hat{P}_n^{jk} / \hat{P}_n^{ks} \Big]^{-\rho^{jk} \frac{1-\alpha^k}{\alpha^k} \rho^{ks} \beta^s (1-\alpha^s)}
\end{aligned}$$

A.2 Additional derivations of the benchmark model

The benchmark model is similar to the model of Section 3 up to the input bundle cost, which is now given by

$$c_n^s = \lambda^s w_n^{\alpha^s} \prod_{k=1}^{S} \left(P_n^k\right)^{\rho_n^{ks}},$$

where P_n^k is the price of the composite good supplied by sector k in country n and no longer depends on the importing sector s. The price of the composite good P_n^s is

$$P_n^s = \left(\int_0^1 p_n^s(\omega)^{1-\sigma^s} d\omega\right)^{\frac{1}{1-\sigma^s}}$$

and where the price of good ω of sector k is common to all sectors in country n and given by

$$p_n^s(\omega) = \min_i \left[\frac{c_i^s \kappa_{in}^s}{z_i^s(\omega)}\right].$$

In equilibrium, the price index in country n and sector s

$$P_n^s = \zeta^s \left(\sum_{i=1}^{N} T_i^s (c_i^s \kappa_{in}^s)^{-\theta^s}\right)^{-\frac{1}{\theta^s}} = \zeta^s \left(\Phi_n^s\right)^{-\frac{1}{\theta^s}},$$

and the trade share for the goods of sector s between country i and country n

$$\pi_{in}^s = \frac{T_i^s [c_i^s \kappa_{ni}^s]^{-\theta^s}}{\Phi_n^s}.$$

Equilibrium: Let Y_n^s be total production of sector s in country n. In equilibrium, it holds that

$$Y_i^s = \sum_{n=1}^{N} \pi_{ni}^s \left(\beta^s I_n + \sum_{b=1}^{S} \rho^{sb}(1-\alpha^b) Y_n^b\right)$$

where $I_n = w_n L_n$. The labor market clearing is

$$w_i L_i = \sum_{s=1}^{D} \alpha^s Y_n^s.$$

Solving the model in changes: Let a change be defined as the ratio of counterfactual to initial value of variable x, $\hat{x} = \frac{x'}{x}$. The change in the input bundle cost of sector s and country i is

$$\hat{c}_i^s = \hat{w}_i^{\alpha^s} \prod_{k=1}^{S} \left(\hat{P}_i^k\right)^{\rho^{ks}}$$

The change in the trade share from country i to country n of good s

$$\hat{\pi}_{in}^{s} = \left[\frac{\hat{c}_i^s \hat{\kappa}_{in}^s}{\hat{P}_n^s}\right]^{-\theta^s}$$

where the change in the price index is

$$\hat{P}_n^s = \left(\sum_{i=1}^{N} \pi_{in}^s (\hat{c}_i^s \hat{\kappa}_{in}^s)^{-\theta^s}\right)^{-\frac{1}{\theta^s}}.$$

One can solve for the counterfactual equilibrium with the counterfactual values of trade shares.

B Numerical algorithm

For any change in bilateral trade costs $\hat{\kappa}_{in}^{sb}$, I solve the model in changes with the following algorithm:

1. Guess a (change in the) wage vector $\hat{\mathbf{w}} = (\hat{w}_1, \ldots, \hat{w}_N)$ for all $n = 1, \ldots, n$.
2. Solve for the (change in the) price of the composite good $\hat{P}_n^{sb}$ and the (change in the) input bundle costs $\hat{c}_i^s$ that satisfy equations (11) and (12).
3. Given the initial values of import shares π_{in}^{sb}, solve for the counterfactual import shares ${\pi_{in}^{sb}}'$ with equation (13).
4. Solve for the counterfactual values of income I_n' and the counterfactual supply of manufacturing goods in each sector ${Y_n^s}'$ that satisfy equations (14) and (15).[20]
5. Using the calibrated initial equilibrium values of income I_n, update the guess on the wage vector $\hat{\mathbf{w}}^{\mathbf{k}}$ using $\hat{w}_n = I_n'/I_n$ for $n = 1, \ldots, N$.

I repeat these steps until $||\hat{w}_n^{k+1} - \hat{w}_n^k|| < \varepsilon$ for all n and for some tolerance level ε.

C Data appendix

AIOT: The Asian Input-Output Tables (AIOT) are a project from the Institute for Developing Economies - Japan External Trade Organization (IDE-JETRO) and contain detailed information on trade by end-use among 9 Asian countries (China, Thailand, Taiwan, Malaysia, Singapore, Korea,

[20]The wage in the US is set as the numéraire.

Indonesia, the Philippines, Japan) plus the US and a constructed rest of the world. I use the 2005 tables, but the tables are available for four additional years (1985, 1990, 1995, 2000).

The advantage of the AIOT is that countries are required to conduct national firm-level surveys to distinguish the origin of input purchases, as well as the use of foreign inputs by country of origin. With the exception of the rest of the world (ROW), imports are allocated to industries without relying on the proportionality assumption. The AIOT thus report how much sector k in country n imports from sector j of country i without relying on the proportionality assumption. The AIOT have 76 sectors, which translate to 25 two-digit ISIC revision 3 sectors, and cover agriculture, mining, manufacturing and services. Table 6 reports the concordance.

WIOT: The World Input-Output Tables (WIOT) provide consistent, global input-output tables. I use the 2013 release, which covers 40 countries plus ROW for the period 1995-2011, and 35 sectors classified according to the International Standard Industrial Classification revision 3 (ISIC Rev. 3). I restrict the sample to the 30 largest economies for computational tractability and concord the 35 sectors to the 25 sectors as described in Table 6.

Underlying assumptions: Two assumptions must be mentioned relative to the construction of the two sets of trade shares. First, although the AIOT contain exports to and from ROW for all countries, they do not record domestic linkages for ROW. I use the WIOT to complement the AIOT. I sum up all trade flows, value added and gross production values across countries included in the WIOT but outside of the AIOT sample (Japan, Korea, US, China, Indonesia, and Taiwan) and create an AIOT-consistent ROW. I also have data on trade flows between ROW and Japan, Korea, US, China, Indonesia, and Taiwan but am missing import shares by ROW from Thailand, Philippines, Singapore, and Malaysia. I thus assign exports of sector s of Thailand, Philippines, Singapore, and Malaysia to an importing sector b of ROW using the median weight of sector b of ROW in the imports from sector s.

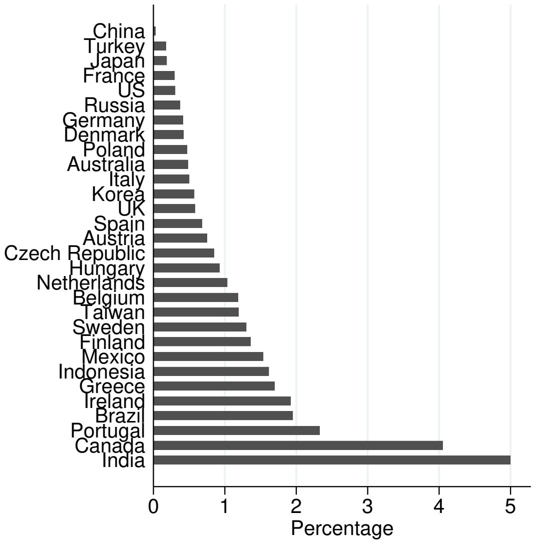
Second, in some rare cases, the data suggest that a sector does not import from home ($\pi_{nn}^{sb} = 0$), complicating the convergence of the numerical algorithm. To avoid this issue, I assume that, in such cases, the sector imports 0.01% of their total trade value from home. I set $\tilde{X}_{nn}^{sb} = 0.0001 * \sum_{i \neq n} X_{in}^{sb}$ for $i = n$, and adjust the existing trade flows to keep total value unchanged, namely: $\tilde{X}_{in}^{sb} = (1 - 000.1) X_{in}^{sb}$ for $i \neq n$. This adjustment concerns less than 1% of observations in the AIOT and in the WIOT.

Table 6: Sector classification and concordance

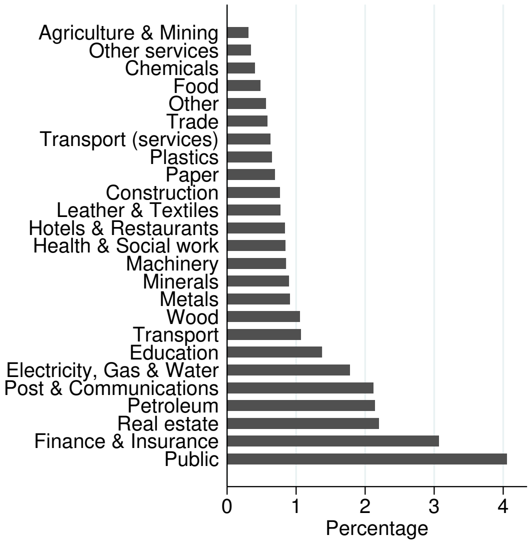
	AIOT sector	ISIC revision 3	Description
1	1-11	1,2,5,10-14	Fishing; Forestry; Agriculture; Mining and Quarrying
2	12-17	15,16	Food and beverages; Tobacco products
3	18-23	17-19	Leather and Textiles
4	24-26	20	Wood
5	27,28	21,22	Paper
6	34,35	23	Coke, refined petroleum products and nuclear fuel
7	29-33	24	Chemicals
8	36,37	25	Rubber and plastics products
9	38-40	26	Other non-metallic mineral products
10	41-43	27-28	Metals
11	44-54	29-33	Machinery and equipment n.e.c.; Office; Radio, television and communication
12	55-58	34-35	Motor vehicles, trailers and semi-trailers; Other transport equipment
13	60	36,37	Other
14	61,62	40,41	Electricity, gas, water
15	63,64	45	Construction
16	65	50-52	Retail and Wholesale trade
17	72,73	55	Hotels and restaurants
18	66	60-63	Transport
19	67	64	Post and telecommunications
20	68	65-67	Finance; Insurance and pension funding, except compulsory social security
21	69	70	Real estate
22	74,76	71-74,90-93,95,99	Other services
23	75	75	Public administration and defense; Social security
24	70	80	Education
25	71	85	Health and social work

Notes: This table describes the sector classification used in the analysis and the concordance between the AIOT classification and the ISIC revision 3 classification.

Figure 7: Zero trade in the WIOT



(a) By importing country



(b) By importing sector

Notes: This figure displays the percentage of zero trade shares in the WIOT following equation (21), i.e., $\pi_{in}^{sb} = 0$ for any $i \neq n$, per (a) importing country and (b) importing sector. Trade shares, in which the rest of the world (ROW) is the importer, are excluded. Trade shares, in which the corresponding input-output linkages are zero ($\pi_{in}^{sb} = 0$ or $\pi_{in}^{s} = 0$ and $\rho^{sb} = 0$), are also excluded.
Sources: 2005 WIOT.

D Additional Tables

Table 7: Calibration of sectoral parameters

		AIOT		WIOT	
Sector	θ^s	β^s	α^s	β^s	α^s
Agriculture & Mining	9.1	3	0.54	1.9	0.54
Food	2.6	6.3	0.29	5.6	0.27
Leather & Textiles	8.1	1.6	0.31	1.6	0.34
Wood	11.5	0.4	0.34	0.1	0.34
Paper	16.5	0.5	0.34	1	0.38
Petroleum	64.8	1.6	0.25	1.3	0.16
Chemicals	3.1	1.1	0.3	1.8	0.3
Plastics	1.7	0.1	0.33	0.4	0.33
Minerals	2.4	0.1	0.34	0.2	0.39
Metals	5.1	0.7	0.28	0.8	0.31
Machinery	5	10.4	0.26	5.6	0.33
Transport	1.1	4.9	0.25	3.8	0.25
Other	4	0.7	0.32	1.2	0.34
Electricity, Gas & Water	5	1.7	0.42	1.5	0.4
Construction	5	11.4	0.35	11.4	0.41
Trade	5	10.6	0.67	11	0.61
Hotels & Restaurants	5	4.1	0.43	3.6	0.5
Transport (services)	5	2.8	0.45	3.3	0.49
Post & Communications	5	1.8	0.59	1.8	0.57
Finance & Insurance	5	4.3	0.63	2.9	0.63
Real estate	5	6.1	0.77	9.7	0.75
Other services	5	7.4	0.55	7.1	0.59
Public	5	9.3	0.6	9.1	0.7
Education	5	5.4	0.65	5.6	0.8
Health & Social work	5	3.7	0.55	7.6	0.65

Notes: This table reports the calibrated values of the trade elasticities θ^s, value added shares α^s and consumer spending shares β^s used in the AIOT and WIOT calibration.
Sources: 2005 AIOT, 2005 WIOT, Caliendo and Parro (2015).

Table 8: Welfare gains in the AIOT calibration

	Augmented model				Benchmark (Caliendo and Parro, 2015)				Deviation (%)
	Total	Final goods	Intermediate goods	Sectoral linkages	Total	Final goods	Intermediate goods	Sectoral linkages	
Country	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
China	6.1	1.7	4.5	-0.0	4.3	1.5	4.1	-1.3	41.5
Indonesia	10.3	2.0	9.4	-1.0	7.7	2.4	7.3	-2.0	34.6
Japan	7.7	1.6	4.6	1.6	4.6	1.5	3.7	-0.5	66.0
Korea	9.0	1.9	6.7	0.6	7.1	2.2	6.0	-1.1	27.6
Malaysia	16.1	6.5	15.5	-6.1	15.3	5.4	14.6	-4.9	5.7
Philippines	17.3	5.6	16.3	-4.7	15.6	6.2	15.2	-6.2	11.0
Singapore	34.8	17.3	27.5	-8.8	31.4	12.5	29.4	-11.1	10.8
Thailand	19.3	5.4	18.6	-4.8	15.9	5.0	15.3	-4.4	21.2
Taiwan	16.0	4.9	12.7	-1.1	14.0	5.1	12.8	-4.0	14.6
US	7.9	3.1	6.8	-2.1	7.7	2.9	7.3	-2.5	1.7

Notes: This table reports augmented and benchmark welfare gains from trade for the AIOT calibration, in percent. Columns (1) to (4) report the welfare gains from trade in the augmented model, i.e. the absolute percentage change in real income and the decomposition of this change following equation (16) associated with moving from a world without international trade, i.e., $\kappa_{in}^{sb} = \infty$ for all $i \neq n$, to the observed equilibrium. Column (5) to (8) report the welfare gains from trade and decomposition under the benchmark model of Caliendo and Parro (2015). Column (9) reports by how much, in percent, the prediction of the augmented model deviates from the benchmark model.

Table 9: Cross-country decomposition of welfare gains deviation across models – WIOT calibration

	Augmented model				Benchmark (Caliendo and Parro, 2015)				Deviation (%)
	Total	Final goods	Intermediate goods	Sectoral linkages	Total	Final goods	Intermediate goods	Sectoral linkages	
Country	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Australia	10.5	6.2	7.0	-2.6	10.4	4.8	9.6	-4.1	0.7
Austria	29.1	13.9	26.9	-12.7	27.1	13.4	25.7	-13.2	7.4
Belgium	41.0	20.0	38.3	-19.4	35.5	17.3	33.5	-17.2	15.6
Brazil	3.2	0.8	3.9	-1.6	3.0	1.2	2.7	-1.0	9.1
Canada	18.2	10.2	14.9	-7.0	17.9	8.7	16.7	-7.9	1.7
China	3.4	1.6	2.6	-0.8	3.2	1.4	2.7	-0.9	7.8
Czech Republic	15.9	7.5	13.2	-4.7	15.2	6.5	14.0	-5.5	4.6
Germany	13.1	5.3	11.0	-3.1	11.9	5.0	10.7	-3.9	10.0
Denmark	43.4	25.3	38.3	-22.7	39.3	21.3	37.3	-23.2	10.5
Spain	13.9	7.5	9.4	-2.6	12.0	5.5	11.0	-4.7	16.1
Finland	18.5	9.7	14.8	-6.0	17.3	8.5	16.3	-8.0	6.7
France	13.7	5.4	11.0	-2.5	11.1	4.9	10.2	-4.0	23.0
UK	15.0	7.1	13.6	-5.9	14.1	6.6	12.8	-5.5	6.5
Greece	19.9	9.9	14.6	-4.1	18.4	9.0	17.2	-8.3	7.7
Hungary	19.5	8.3	18.0	-7.0	18.8	8.6	17.7	-7.9	3.6
Indonesia	16.1	2.7	21.6	-10.1	8.9	3.1	8.4	-2.6	81.3
India	4.8	1.6	4.6	-1.4	4.2	1.8	3.5	-1.2	14.3
Ireland	25.9	14.8	20.2	-9.0	24.8	12.7	23.2	-12.1	4.4
Italy	10.3	5.0	7.8	-2.4	9.6	4.4	8.8	-3.6	7.3
Japan	3.7	1.9	2.0	-0.1	3.1	1.2	2.5	-0.6	19.0
Korea	6.7	2.6	4.7	-0.4	4.5	1.6	3.8	-0.9	49.5
Mexico	12.7	4.2	14.6	-6.7	12.0	5.2	11.3	-4.7	6.1
Netherlands	32.5	15.7	30.1	-14.5	28.9	13.7	27.6	-13.8	12.3
Poland	16.2	7.2	15.1	-6.4	15.1	7.0	14.1	-6.3	7.0
Portugal	21.2	9.6	18.5	-6.8	19.3	9.2	18.1	-8.5	10.3
Russia	9.0	5.2	7.1	-3.4	8.5	4.2	7.8	-3.6	5.1
Sweden	16.7	6.8	14.3	-4.2	14.4	6.2	13.3	-5.2	16.1
Turkey	15.2	7.1	13.4	-5.4	13.5	6.6	12.8	-6.2	12.3
Taiwan	14.4	5.6	13.4	-4.7	11.7	5.0	10.2	-3.5	23.5
US	6.2	3.1	4.6	-1.5	6.1	2.7	5.5	-2.1	1.6

Notes: This table reports augmented and benchmark welfare gains from trade for the WIOT calibration, in percent. Columns (1) to (4) report the welfare gains from trade in the augmented model, i.e. the absolute percentage change in real income and the decomposition of this change following equation (16) associated with moving from a world without international trade, i.e., $\kappa_{in}^{sb} = \infty$ for all $i \neq n$, to the observed equilibrium. Column (5) to (8) report the welfare gains from trade and decomposition under the benchmark model of Caliendo and Parro (2015). Column (9) reports by how much, in percent, the prediction of the augmented model deviates from the benchmark model.

Table 10: Deviation between the augmented and benchmark welfare gains – full WIOT results

Country	Total (1)	Final goods (2)	Intermediate goods (3)	Sectoral linkages (4)
Australia	0.1	1.4	-2.5	1.4
Austria	2.0	0.5	1.3	0.5
Belgium	5.5	2.7	4.8	-2.2
Brazil	0.3	-0.4	1.2	-0.6
Canada	0.3	1.5	-1.8	0.9
China	0.2	0.2	-0.1	0.1
Czech Republic	0.7	1.0	-0.9	0.8
Germany	1.2	0.3	0.3	0.7
Denmark	4.1	3.9	0.9	0.5
Spain	1.9	1.9	-1.6	2.1
Finland	1.2	1.2	-1.5	2.0
France	2.6	0.5	0.8	1.5
UK	0.9	0.6	0.8	-0.4
Greece	1.4	0.9	-2.6	4.1
Hungary	0.7	-0.3	0.2	0.9
Indonesia	7.2	-0.4	13.3	-7.5
India	0.6	-0.2	1.1	-0.3
Ireland	1.1	2.1	-3.0	3.1
Italy	0.7	0.6	-1.0	1.3
Japan	0.6	0.7	-0.5	0.5
Korea	2.2	0.9	0.9	0.5
Mexico	0.7	-1.0	3.3	-2.0
Netherlands	3.6	1.9	2.5	-0.7
Poland	1.1	0.2	0.9	-0.0
Portugal	2.0	0.4	0.4	1.7
Russia	0.4	1.0	-0.7	0.1
Sweden	2.3	0.6	1.0	1.0
Turkey	1.7	0.5	0.6	0.8
Taiwan	2.7	0.6	3.3	-1.2
US	0.1	0.4	-0.9	0.6

Notes: This table reports the deviation between augmented and benchmark welfare gains across countries, and its decomposition. Column (1) reports the deviation (in percentage points) between the gains from trade predicted by the augmented model and by the benchmark model of Caliendo and Parro (2015). Columns (2) to (4) report the decomposition of the deviation in gains from trade into the final goods effect, the intermediate goods effect, and the sectoral linkages effect following equation (16). Results for the AIOT calibration are reported in Table 4.

Table 11: Deviation between the augmented and benchmark sectoral contributions to the country-level welfare change (in pp) – AIOT calibration

	Country									
Sector	CHN	IDN	JPN	KOR	MYS	PHL	SGP	THA	TWN	USA
Agriculture & Mining	-0.3	0.5	-5.7	-8.2	-1.5	0.3	0.3	-3.0	-4.5	-3.0
Food	0.8	1.8	-0.3	-0.8	3.7	1.5	5.0	0.4	-0.2	-1.1
Leather & Textiles	1.5	4.7	9.3	4.8	2.1	2.0	3.3	1.6	5.8	0.2
Wood	1.4	1.5	5.5	4.1	2.0	1.3	1.3	-0.2	4.9	0.4
Paper	3.4	2.8	3.2	2.8	-0.8	2.6	-0.0	9.7	4.7	-0.1
Petroleum	12.1	10.9	23.2	17.5	-0.9	15.3	-7.2	14.1	18.6	2.5
Chemicals	3.1	11.0	6.8	5.7	2.7	-0.1	7.7	3.7	10.8	3.3
Plastics	15.9	8.1	20.3	25.6	23.9	4.3	3.3	15.6	13.9	11.8
Minerals	1.6	7.5	9.8	25.4	13.3	14.1	15.8	17.0	6.0	19.2
Metals	8.1	0.4	10.2	4.3	-5.8	1.0	-3.0	-11.6	2.0	1.2
Machinery	3.4	5.7	4.1	3.0	4.3	-0.2	-1.1	9.5	5.1	1.2
Transport	5.9	7.4	3.9	2.2	-3.0	1.2	10.5	11.8	0.1	2.1
Other	3.5	6.4	5.8	11.7	-0.5	7.8	4.7	5.7	6.4	4.2
Electricity, Gas & Water	2.1	1.5	15.6	10.4	0.1	4.0	-6.0	2.1	8.7	-0.3
Construction	1.5	2.2	3.0	1.5	-0.5	3.9	-1.9	1.6	1.1	-0.9
Trade	0.6	0.7	1.7	1.1	-0.1	1.3	-1.2	0.5	1.0	0.0
Hotels & Restaurants	1.0	0.3	2.2	0.5	-2.4	1.1	-0.4	0.4	-0.7	0.0
Transport (services)	2.9	3.8	5.9	4.5	0.1	4.3	-1.1	3.5	5.4	-0.0
Post & Communications	0.4	0.4	1.1	0.8	0.6	0.4	-0.2	-0.5	0.3	0.0
Finance & Insurance	0.3	0.3	0.6	0.4	0.1	0.5	-0.2	0.1	0.3	-0.1
Real estate	0.2	0.3	0.6	0.3	-0.0	0.5	-0.3	0.1	0.3	-0.1
Other services	0.9	1.5	1.4	1.0	0.2	1.0	0.1	0.1	0.7	-0.3
Public	1.0	1.1	3.5	2.9	3.1	1.9	-2.8	0.2	0.9	-0.4
Education	0.6	0.7	1.8	1.4	0.6	1.2	-1.0	0.1	0.8	-0.2
Health & Social work	0.5	2.8	2.8	0.9	0.8	-0.7	-1.5	3.9	2.5	0.1

Notes: AIOT calibration. This table presents the deviation between the augmented and benchmark contributions to aggregate welfare gains, given by equation (17).

Table 12: Deviation between the augmented and benchmark sectoral contributions to the country-level welfare change (in pp) – WIOT calibration

	Country														
Sector	AUS	AUT	BEL	BRA	CAN	CHN	CZE	DEU	DNK	ESP	FIN	FRA	GBR	GRC	HUN
Agriculture & Mining	-2.1	-1.9	1.7	-0.8	-3.4	-1.3	-1.7	0.2	-1.1	-3.5	-2.6	-0.5	-1.5	-0.8	-2.2
Food	0.1	2.0	6.6	0.2	-0.4	0.1	0.7	-0.4	6.9	1.6	1.1	2.1	4.5	1.7	0.1
Leather & Textiles	0.7	3.3	8.4	0.3	1.1	-0.2	1.8	3.2	10.4	2.3	0.4	5.7	-0.2	2.2	1.3
Wood	-1.0	-0.8	-1.7	0.5	-1.9	0.2	0.5	-1.6	-0.3	-0.6	0.2	0.8	-2.6	-0.4	-2.0
Paper	-0.8	2.6	0.5	0.3	-1.9	1.0	-0.7	0.3	1.6	0.3	0.2	2.1	-0.8	1.0	0.0
Petroleum	0.2	12.3	27.8	1.3	-0.1	2.5	8.7	18.5	0.4	25.5	20.2	38.2	-0.7	45.7	18.1
Chemicals	3.4	7.4	-0.6	-1.8	14.3	5.9	1.4	1.4	6.7	0.0	7.3	-0.5	10.1	3.1	1.7
Plastics	-4.1	5.6	-4.5	6.5	1.5	10.8	0.0	4.1	7.8	22.8	9.4	6.4	-3.2	-6.7	-7.5
Minerals	0.9	-2.5	-3.7	1.7	-4.1	0.7	0.7	-2.6	5.3	8.1	2.5	2.2	-1.4	3.8	-6.4
Metals	-1.1	-3.6	0.7	-0.1	-0.2	0.7	-0.6	-0.9	3.3	1.2	2.7	1.4	0.7	1.9	-2.7
Machinery	1.6	2.8	5.0	0.8	3.7	-0.5	4.3	2.5	4.3	8.0	1.6	5.5	2.4	6.1	-0.2
Transport	3.9	0.5	1.0	-2.7	1.6	-0.0	0.6	1.7	0.1	4.2	0.7	1.4	1.9	-2.2	0.9
Other	-0.0	3.7	11.5	0.2	2.5	4.6	18.0	0.9	11.6	3.2	7.0	3.8	0.8	1.4	1.4
Electricity, Gas & Water	-0.7	4.6	5.9	0.6	-0.8	0.0	0.8	1.6	0.1	4.4	2.4	9.4	-0.4	2.8	6.1
Construction	-1.2	0.9	1.3	0.4	-1.8	-0.0	-0.8	0.6	-0.7	-0.1	-0.2	2.0	-0.3	1.2	0.6
Trade	-1.1	0.5	0.9	0.5	-1.6	0.0	-0.3	0.2	0.7	0.0	2.2	1.4	-0.1	1.1	0.4
Hotels & Restaurants	-1.4	-1.6	-3.4	0.2	-2.3	-0.2	-1.9	-1.0	-2.8	-1.0	-1.1	0.1	-2.5	-0.1	-0.5
Transport (services)	-1.3	2.9	3.6	0.7	-0.1	0.1	0.7	3.7	3.0	1.5	0.7	4.9	1.1	2.2	1.1
Post & Communications	-0.2	1.6	1.0	0.3	-2.2	0.2	0.2	1.5	0.4	0.1	0.2	1.0	1.1	0.7	0.4
Finance & Insurance	-0.2	-0.1	-0.0	0.3	-0.7	0.0	-0.2	0.1	-0.3	0.1	0.0	0.7	-0.1	0.3	-0.0
Real estate	-0.2	0.1	0.2	0.1	-0.6	0.0	-0.1	0.0	-0.3	0.0	-0.0	0.5	-0.1	0.4	0.1
Other services	-0.4	-0.5	0.0	0.3	-1.5	0.1	-0.4	0.1	-0.6	0.1	-0.1	1.1	-0.4	0.7	0.2
Public	-0.6	-0.5	0.8	0.9	-0.8	0.1	-0.2	2.0	0.3	-0.4	-1.0	1.1	1.4	1.0	-0.0
Education	-0.2	0.2	0.4	0.2	-0.8	0.1	-0.1	0.3	-0.2	0.2	0.0	0.8	-0.1	0.5	0.2
Health & Social work	0.1	3.6	3.4	0.6	-0.5	0.0	-0.0	1.1	2.4	0.8	-0.1	1.8	-0.2	1.4	0.4

Notes: WIOT calibration. This table presents the deviation between the augmented and benchmark contributions to aggregate welfare gains, given by equation (17).

Table 13: Deviation between the augmented and benchmark sectoral contributions to the country-level welfare change (in pp) – WIOT calibration (continued)

	Country														
Sector	IDN	IND	IRL	ITA	JPN	KOR	MEX	NLD	POL	PRT	RUS	SWE	TUR	TWN	USA
Agriculture & Mining	3.7	-0.9	-3.0	-4.9	-5.2	-7.4	0.5	-3.2	-1.1	-2.6	-0.0	-0.3	-0.8	-9.2	-3.1
Food	5.5	-0.7	14.0	0.8	-0.3	-0.1	0.8	5.8	-0.1	2.5	-0.5	1.6	0.1	-1.2	-0.1
Leather & Textiles	6.8	0.4	9.0	1.0	5.6	1.8	0.2	9.5	5.4	1.2	-0.8	9.0	0.9	8.5	3.5
Wood	54.3	4.0	-3.0	0.3	-1.4	5.6	-1.1	-0.7	-1.0	-0.4	-0.3	0.9	0.4	0.3	-1.1
Paper	6.3	0.4	-1.5	-0.0	0.7	1.6	0.4	1.1	-0.6	1.4	-0.0	2.7	0.5	1.9	-0.1
Petroleum	7.3	7.7	12.1	11.6	6.4	20.6	0.4	1.1	7.1	34.9	-1.2	23.8	21.1	18.0	2.1
Chemicals	-1.3	-1.6	0.3	-0.3	7.1	18.8	-4.1	4.0	-0.8	3.3	24.3	6.2	-1.7	8.7	0.8
Plastics	1.5	1.5	-3.6	-0.3	12.9	18.8	20.6	0.3	16.6	-2.2	-0.2	7.6	-0.2	-1.0	11.4
Minerals	6.9	3.3	-0.0	1.2	6.9	14.6	-3.0	-2.1	-2.7	2.3	-0.2	-1.3	2.2	-0.1	5.8
Metals	20.6	-2.4	1.2	-0.4	0.2	11.5	-3.5	2.7	-2.9	0.2	2.6	-1.2	-3.6	3.0	2.1
Machinery	12.8	0.1	-0.2	2.0	1.0	4.6	0.3	5.9	5.1	3.2	0.4	3.8	1.3	5.2	1.0
Transport	8.2	-0.2	0.0	3.2	2.4	4.3	0.4	1.5	1.1	0.9	1.1	4.4	3.1	-2.1	0.6
Other	9.1	2.5	3.1	2.0	5.6	5.5	0.0	7.8	4.6	3.3	0.8	8.3	0.4	25.7	0.1
Electricity, Gas & Water	6.3	1.1	4.5	4.7	2.4	7.6	0.9	0.4	0.4	12.7	-0.7	3.8	7.0	9.5	0.6
Construction	9.5	0.9	-0.3	0.1	0.2	1.6	0.4	2.3	0.3	0.6	-0.7	1.3	0.6	2.1	-0.5
Trade	11.9	1.0	-0.5	0.2	0.0	1.0	1.4	0.3	0.2	1.1	-0.2	0.4	0.9	1.3	-0.2
Hotels & Restaurants	3.9	1.9	-3.7	-1.1	-1.1	-0.3	0.9	-2.2	-0.2	-0.9	-0.6	-1.3	0.9	0.6	-0.5
Transport (services)	3.8	1.1	-0.9	0.6	1.0	3.6	2.5	-0.4	2.1	3.0	-1.0	2.8	2.0	4.3	-0.1
Post & Communications	4.5	0.3	0.0	-0.0	-0.1	1.3	0.6	-0.3	1.5	0.7	-0.4	0.5	0.4	1.8	0.2
Finance & Insurance	1.7	0.3	-0.2	0.0	0.0	0.7	0.2	-0.2	0.1	0.2	-0.1	0.1	0.3	1.4	0.1
Real estate	2.0	0.3	-0.1	0.0	0.0	0.5	0.2	0.1	-0.0	0.2	-0.1	0.2	0.2	1.7	-0.0
Other services	2.4	1.4	-0.5	0.0	-0.0	0.6	0.6	-0.6	0.2	0.4	-0.4	0.1	0.4	1.0	-0.1
Public	11.5	-0.2	-0.8	-0.3	0.2	0.6	1.0	-0.1	-0.2	0.9	0.0	0.4	-0.4	0.7	-0.2
Education	2.3	0.6	-0.1	0.0	0.0	0.7	0.3	-0.0	0.0	0.6	-0.2	0.2	0.4	0.7	-0.0
Health & Social work	4.2	0.5	0.1	0.3	0.0	1.2	1.1	3.3	0.7	0.8	-1.0	2.5	0.9	5.6	-0.4

Notes: WIOT calibration. This table presents the deviation between the augmented and benchmark contributions to aggregate welfare gains, given by equation (17).

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