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Abstract

Multi-stage production is widely recognized as an important feature of the modern global economy. This feature has been incorporated into many state-of-the-art quantitative trade models, and has been shown to deliver significant additional gains from international trade. Meanwhile, specialization across stages of production, or "vertical specialization," has been largely ignored in these models. In this paper, I provide evidence that vertical specialization is a salient feature in the international trade data, which implies that the assumption made in standard models is inaccurate. I then develop a model with multi-stage production where country-level productivity differences provide a basis for vertical specialization and additional global gains from trade beyond those currently accounted for in standard models. I quantify the gains from vertical specialization according to the model. Despite the importance of vertical specialization in the data, I find that the average gains from trade are only slightly higher than the gains suggested by standard models with multi-stage production. Moreover, much of the impact of across-stage specialization is largely offset by across-sector intermediate input linkages. These results suggest that vertical specialization is not the source of missing gains from trade that have recently confounded trade economists.

Bank topics: Trade integration; Economic models; International topics
JEL codes: F11; F14; F60

Résumé

Il est généralement reconnu que la segmentation des processus de production est une caractéristique importante de l'économie mondiale actuelle. Ce fractionnement du processus de production en plusieurs étapes a été incorporé à de nombreux modèles quantitatifs modernes du commerce, et il a été démontré qu'il produit des gains additionnels importants sur le plan du commerce international. Toutefois, la plupart de ces modèles ont négligé les effets de la spécialisation aux différentes étapes du processus de production, ou « spécialisation verticale ». Dans la présente étude, je fournis des données qui révèlent que la spécialisation verticale est un aspect fondamental du commerce international, ce qui porte à croire que l'hypothèse intégrée aux modèles standard est inexacte. J'élabore ensuite un modèle incorporant un processus de production fragmenté dans lequel les écarts de productivité entre les pays servent de base à l'évaluation de la spécialisation verticale et des gains additionnels à l'échelle mondiale issus du commerce qui ne sont pas pris en compte dans les modèles standard. Je quantifie les gains que procure la spécialisation verticale d'après le modèle. Je constate que malgré l'importance qu'occupe la spécialisation verticale dans les données, les gains moyens sur le plan des échanges sont seulement un peu plus élevés que ce qu'indiquent les modèles standard qui incorporent un processus de production en plusieurs étapes. De plus, une grande part de l'incidence de la spécialisation aux différentes étapes du processus de production est contrebalancée dans une large mesure par les liens intersectoriels relatifs aux intrants intermédiaires. Ces résultats donnent à penser que la spécialisation verticale n'est pas la cause de l'absence de gains découlant des échanges internationaux qui a récemment déconcerté les économistes spécialisés en commerce.

Sujets : Intégration des échanges ; Modèles économiques ; Questions internationales
Codes JEL : F11 ; F14 ; F60

Non-Technical Summary

Multi-stage production (MSP) is a widely examined feature of the modern global economy. It refers to the way in which more products are generated, with not only value-added (e.g., labour), but also intermediate products as inputs. These intermediate products are often themselves also produced with other intermediates, giving rise to a sequential chain of production stages.

In this paper, I examine how MSP affects the economic gains from international trade. I first provide empirical evidence that, rather than importing similar shares of intermediate and final products for a given sector, many countries vertically specialize in producing a larger share of one type of product, and import a higher share of the other. This phenomenon has been largely ignored in standard international trade models that incorporate MSP.

I then develop a model where country-level productivity differences across stages of production provide a basis for gains from trade due to vertical specialization (VS) that are unaccounted for by these standard models. I show that these gains are theoretically uneven along the value chain, and potentially large depending on parameters in the data.

I take the model to a data set that includes 34 countries and 31 sectors. I show that intermediate inputs tend to account for a larger share of total output than value-added for most tradable sectors, which implies that the gains from VS are potentially large for downstream producers that import intermediates and specialize in final assembly, like China and Mexico. These potential gains are, however, largely attenuated as a result of intermediate input linkages across sectors, which dampen the effect of VS on the gains from trade.

In the end, I find that the overall gains from VS are modest for all countries examined. This suggests that VS is not the source of the missing gains from trade that have recently confounded trade economists.

1 Introduction

The notion of multi-stage production (MSP) has gained wide currency in international trade (Antras and Chor, 2013; Hummels et al., 2001; Yi, 2003, 2010). MSP refers to the sequential manner in which most goods and services are produced, where a given product uses intermediate products as inputs, which are themselves produced with other intermediate inputs, and so forth.[1]

The nature of this production structure has important implications for productivity and the gains from international trade. As has long been acknowledged by trade economists (e.g., Krugman and Venables, 1995), trade in intermediate inputs provides a magnification effect that raises welfare significantly more than trade in final goods alone. This effect is typically captured by assuming a "roundabout" production (RP) structure, which delivers a sizable welfare impact (see Costinot and Rodriguez, 2014).

Although the roundabout assumption is convenient in a number of ways, it abstracts from an additional channel whereby MSP might facilitate gains from trade (GFT), namely, through specialization across production stages or "vertical specialization" (VS). Recently, Melitz and Redding (2014) emphasize the potential importance of VS in the context of an Armington model. They argue that MSP, combined with VS, might be a source for the "missing gains from trade" that have confounded trade economists in recent years (see Arkolakis et al. 2012).

Figure 1 presents a scatter plot of separate home expenditure shares for intermediate and final products across a set of 34 countries and 31 sectors from 2005.[2] According to the standard RP assumption, these shares should be identical across intermediate and final products for a given country-sector pair, which corresponds to the 45-degree line in the figure. The fact that many points in the figure lie off the 45-degree line reveals the importance of VS in the international trade data, and implies that the roundabout assumption is empirically inaccurate.

In this paper, I develop an augmented Eaton and Kortum (2002) model with MSP where technological differences across countries provide a basis for VS and gains from international trade. The model provides similar insights and tractability as Melitz and Redding (2014) while contributing additional richness and comparability with other recent models (e.g., Caliendo and Parro, 2015). I show that, at the country level, the GFT suggested by the model with VS could be higher or lower than the gains suggested by a model that assumes RP, and that these gains are potentially uneven for upstream and downstream producers, depending on parameters in the data.

[1] MSP is also commonly referred to as sequential production.

[2] Home consumption share is equal to (1 - import penetration share). These shares are derived based on data from the World Input-Output Database.

I then take the model to cross-country sector-level trade and production data constructed from the World Input-Output Database (WIOD). I find that, although VS is a salient feature in the trade data, the additional welfare gains from VS are very modest for all countries compared with the GFT suggested by the standard models with RP. On average, the additional gains are less than 1% of gross domestic product (GDP).

For some countries, the model without VS actually provides an inflated estimate for the GFT. That is, rather than unveiling the "missing gains from trade," including VS in the model can imply lower GFT compared with standard models that assume RP. These findings suggest that VS, while an important feature of the data, does not provide significant GFT above those suggested by standard models that incorporate MSP.

Overall, the results found here contribute to several strands of literature. The focus on MSP contributes to recent literature that explores the importance of placement on the value chain. This literature is vast, focusing on topics such as the determinants of sequential position (Costinot, Vogel and Wang, 2013; Oberfield, 2014), firm boundaries (Antras, 2003; Antras and Chor, 2013) and magnification of shocks (di Giovanni and Levchenko, 2010; di Giovanni, Levchenko and Mejean, 2014; Jones, 2011).

I find that, for the average sector, there are greater economic gains from being downstream rather than upstream in the trade relationship since imported intermediates provide additional GFT through the input-output (IO) loop. This result is also supported by Melitz and Redding (2014) and Fally and Hilberry (2015). I also find that emerging economies tend to be placed more downstream, which is consistent with findings by Antras et al. (2012) and perhaps reflective of the role that final processing plays in these economies.[3]

Although there are generally greater economic GFT for downstream producers, the opposite is true for some sectors where intermediate inputs are less important than value-added in production. Moreover, empirically, intermediate input linkages largely attenuate these additional downstream gains. This relates to a strand in the literature that focuses on the importance of cross-sectional input linkages in affecting economic outcomes (Acemoglu et al., 2012, 2015; Caliendo and Parro, 2015).

These results also relate to recent literature that attempts to identify the role of comparative advantage in empirical trade flows (Chor, 2010; Costinot and Donaldson, 2012; Costinot, Donaldson and Kumunjer, 2012). A subset of this literature focuses on quantifying the GFT due to specialization across sectors, finding that these gains are significant (Caliendo and Parro, 2015; French, 2016; Levchenko and Zhang, 2014; Ossa, 2015). I find that across-sector specialization is more important than across-stage

[3]Antras et al. (2012) develop an empirical measure of upstreamness based on sector-level trade data. They find that, controlling for rule of law and private credit market strength, advanced economies are generally positioned more upstream in production.

specialization in determining the GFT.

The remainder of the paper is organized as follows. In Section 2, I describe the model. In Section 3, I discuss and summarize the data. In Section 4, I discuss the results. In Section 5, I conclude. An appendix follows.

2 Model

2.1 Environment

Consider the following Eaton and Kortum (2002) model with N countries, indexed by n, and J sectors, indexed by j. There are two types of goods: intermediate (I) and final (F), indexed by s. Consumers in n have labor endowment L_n, which is inelastically supplied, and receive labor income at wage w_n. They derive utility from consuming a final good $C_{F,n}$ that is equivalent to a Cobb-Douglas composite of non-traded sectoral goods denoted by C_n^j:

$$U_n = C_{F,n} = \prod_{j=1}^{J} C_n^{j\,\alpha_n^j}, \tag{1}$$

where $\sum_{j=1}^{J} \alpha_n^j = 1$. The budget constraint for consumers in n is given by:

$$\sum_{j=1}^{J} P_{F,n}^j C_n^j = w_n L_n,$$

where $P_{F,n}^j$ denotes the final good price index in sector j.

The non-traded final good in sector j in n is produced using a continuum of tradable final products indexed by $\omega \in [0, 1]$ according to the following constant elasticity of substitution (CES) production technology:

$$Q_{F,n}^j = \left(\int q_{F,n}^j(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

where $\sigma > 1$ denotes the elasticity of substitution across products and $q_{F,n}^j(\omega)$ denotes the quantity demanded of a given tradable final product ω. I denote the non-traded final good price index as:

$$P_{F,n}^j = \left[\int_0^1 p_{F,n}^j(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}},$$

where $p_{F,n}^j(\omega)$ denotes the price of a given tradable final product ω.

Tradable final products are produced with productivity drawn from a country-sector-specific Fréchet distribution of the following form:

$$F^j_{F,n}(z) = Pr\left(z^j_{F,n} < z\right) = exp\left\{-T^j_{F,n} z^{-\theta}\right\}, \tag{3}$$

where $T^j_{F,n}$ depicts a parameter of country-sector-level average productivity in final products while θ dictates dispersion across productivity draws. The dispersion parameter provides a basis for intra-industry GFT in final products.

These products are produced using productivity $z^j_{F,n}$, combined with labor and non-traded intermediate good inputs. Letting $1 - \beta^j_n$ denote the Cobb-Douglas labor share in production, the final products production technology for ω is:

$$y^j_{F,n}(\omega) = z^j_{F,n}(\omega)\left(l^j_{F,n}(\omega)\right)^{1-\beta^j_n} \prod_{k=1}^{J} \left(M^{k,j}_{F,n}(\omega)\right)^{\beta^{k,j}_n},$$

where $M^{k,j}_{F,n}(\omega)$ denotes the amount of non-traded intermediate good from sector k used in production of product ω in sector j, $\beta^{k,j}_n$ denotes of Cobb-Douglas share of this input, and $\sum_{k=1}^{J} \beta^{k,j}_n = \beta^j_n$.

The non-traded intermediate good in each sector is produced according to a similar technology as the non-tradable final good:

$$Q^j_{I,n} = \left(\int q^j_{I,n}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega\right)^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

where $q^j_{I,n}(\omega)$ denotes the quantity demanded of a given tradable intermediate product ω. I denote the non-tradable intermediate good price index as:

$$P^j_{I,n} = \left[\int_0^1 p^j_{I,n}(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}},$$

where $p^j_{I,n}(\omega)$ denotes the price of a given tradable intermediate product ω.

Tradable intermediate products are also produced with productivity drawn from a country-sector-specific Fréchet distribution:

$$F^j_{I,n}(z) = Pr\left(z^j_{I,n} < z\right) = exp\left\{-T^j_{I,n} z^{-\theta}\right\}. \tag{5}$$

Note that the only manner in which (5) is distinct from (3) comes from the average productivity terms $T^j_{F,n}$ and $T^j_{I,n}$.[4]

[4]In fact, this is essentially the only manner in which this model differs from standard Eaton and Kortum models that incorporate MSP (e.g., Caliendo and Parro, 2015). These models typically assume that $T^j_{F,n} = T^j_{I,n}$ for all n and j, which is consistent with the RP assumption.

Like final products, intermediate products are produced using labor and the non-tradable intermediate goods. The intermediate product production technology for ω is:

$$y^j_{I,n}(\omega) = z^j_{I,n}(\omega) \left(l^j_{I,n}(\omega)\right)^{1-\beta^j_n} \prod_{k=1}^{J} \left(M^{k,j}_{I,n}(\omega)\right)^{\beta^{k,j}_n}.$$

Given the CES production functions in (2) and (4), the non-traded type s good producer in sector j in n has the following demand for expenditure on tradable type s product ω:

$$x^j_{s,n}(\omega) = \left[\frac{p^j_{s,n}(\omega)}{P^j_{s,n}}\right]^{1-\sigma} X^j_{s,n}, \tag{6}$$

where $X^j_{s,n}$ denotes total expenditure in n on type s products in sector j.

2.2 Prices and Expenditure Shares

Product and factor markets are perfectly competitive. All products sold by producers in country i to country n are subject to an *ad valorum* bilateral iceberg transportation cost $\kappa^j_{s,ni}$ where $\kappa^j_{s,ni} > \kappa^j_{s,nn} = 1$. Accordingly, producers of type s products in sector j of country i sell their products in country n at a price equal to marginal cost:

$$p^j_{s,ni}(\omega) = \frac{c^j_i \kappa^j_{s,ni}}{z^j_{s,i}(\omega)},$$

where

$$c^j_i = \Psi^j_i \left(w_i\right)^{1-\beta^j_i} \prod_{k=1}^{J} \left(P^k_{I,i}\right)^{\beta^{k,j}_i}. \tag{7}$$

denotes the unit cost of production and Ψ^j_i is a constant.[5]

Let $\pi^j_{s,ni}$ denote the probability that country i provides the lowest price in country n of a given type s product ω in sector j. Under the Fréchet distribution, this is also equivalent to the total share of products exported from i to n in sector j and can be denoted as the following:

$$\pi^j_{s,ni} = \frac{X^j_{s,ni}}{X^j_{s,n}} = \frac{T^j_{s,i}\left[c^j_i \kappa^j_{s,ni}\right]^{-\theta}}{\phi^j_{s,n}}, \tag{8}$$

where

$$\phi^j_{s,n} = \sum_{i=1}^{N} T^j_{s,i}\left[c^j_i \kappa^j_{s,ni}\right]^{-\theta}.$$

[5] Specifically, $\Psi_i = (1-\beta^j_i)^{\beta^j_i - 1} \prod_{k=1}^{J} (\beta^{k,j}_i)^{-\beta^{k,j}_i}$

That is, for a given good type s in sector j, the share of total spending by n on products from i is positively related to the average productivity parameter, $T^j_{s,i}$, and negatively related to unit cost of production c^j_i and the trade cost $\kappa^j_{s,ni}$. The denominator denotes a multilateral resistance term for total expenditure in n on type s goods in sector j.

We can also simplify the price index equations to the following closed-form solution:

$$P^j_{s,n} = \gamma[\phi^j_{s,n}]^{\frac{1}{-\theta}}, \tag{9}$$

where $\gamma = \Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)^{\frac{1}{1-\sigma}}$ is a constant.[6]

Given the utility function in (1), the aggregated final good price index in n is the following:

$$P_n = \prod_{j=1}^{J} \left(P^j_{F,n}/\alpha^j_n\right)^{\alpha^j_n}.$$

2.3 Total Expenditures

The production technology for tradable intermediate products yields the following expression for total intermediate products expenditure in n:

$$X^j_{I,n} = \sum_{k=1}^{J} \beta^{j,k}_n \sum_{i=1}^{N} \left(X^k_{I,in} + X^k_{F,in}\right). \tag{10}$$

The consumer's utility function yields the following expression for total final goods expenditure in n:

$$X^j_{F,n} = \alpha^j_n w_n L_n. \tag{11}$$

Finally, I restrict total trade balance, D_n, to be equal to zero for all countries. Denoting $D^j_n = \sum_{i=1}^{N} X^j_{ni} - \sum_{i=1}^{N} X^j_{in}$ as country n's total trade surplus in sector j:

$$D_n = \sum_{j=1}^{J} \left(\sum_{i=1}^{N} X^j_{ni} - \sum_{i=1}^{N} X^j_{in} \right) = 0 \tag{12}$$

for all n.[7]

[6] See Eaton and Kortum (2002) for the derivation of results (8) and (9).

[7] Other versions of the Eaton and Kortum (2002) model sometimes allow for trade deficits at the country level. This element could easily be included in this model as well. However, for simplicity, I assume that trade is balanced for each country.

2.4 Equilibrium

Following Alvarez and Lucas (2007) and Caliendo and Parro (2015), I define an equilibrium as a set of wages and prices that satisfy (7), (8), (9), (10), (11), and (12) for all n, j and s.

2.5 Welfare and Gains from Trade

Welfare per capita in n according to this model is equivalent to the following expression for real wage:

$$W_n = \frac{w_n}{P_{F,n}^C} = \prod_{j=1}^{J} \left(\frac{\alpha_n^j w_n}{P_{F,n}^j} \right)^{\alpha_n^j}. \tag{13}$$

To represent the gains from international trade, I follow the "exact hat algebra" approach from Dekle, Eaton and Kortum (2007), denoting $\hat{x} = \acute{x}/x$ as the relative change between some initial value x and counterfactual value $\acute{x}$ of a variable due to a counterfactual change in international trade costs. Using this notation, we can produce the following expressions from equations (7), (8), and (9):

$$\hat{c}_i^j = (\hat{w}_i)^{1-\beta_i^j} \prod_{k=1}^{J} \left(\hat{P}_{I,i}^k \right)^{\beta_i^{k,j}}, \tag{14}$$

$$\hat{\pi}_{s,ni}^j = \frac{\left[\hat{c}_i^j \hat{\kappa}_{s,ni}^j \right]^{-\theta}}{\left[\hat{P}_{s,n}^j \right]^{-\theta}}, \tag{15}$$

$$\hat{P}_{s,n}^j = \left(\sum_{i=1}^{N} \pi_{s,ni}^j \left[\hat{c}_i^j \hat{\kappa}_{s,ni}^j \right]^{-\theta} \right)^{\frac{1}{-\theta}}.$$

To find an expression for the GFT, I first consider the following representation for the relative change in home expenditure share for intermediate products due to a change in trade costs, derived from combining (14) and (15):

$$\hat{\pi}_{I,nn}^j = \prod_{k=1}^{J} \left(\frac{\hat{w}_n}{\hat{P}_{I,n}^k} \right)^{\left(I-\beta_n^{k,j}\right)(-\theta)},$$

where I denotes an indicator function that equals 1 when $k = j$ and equals 0 when $k \neq j$. This expression can be rearranged in terms of real wages and multiplied across j to yield the following:

$$\prod_{k=1}^{J} \frac{\hat{w}_n}{\hat{P}_{I,n}^k} = \prod_{k,j=1}^{J} \hat{\pi}_{I,nn}^j {}^{\frac{-1}{\left(I-\beta_n^{k,j}\right)\theta}}. \tag{16}$$

Turning now to final products, we can derive the following expression from combining (14) and (15):

$$\hat{\pi}^j_{F,nn} = \left[\frac{\hat{w}_n}{\hat{P}^j_{F,n}} \prod_{k=1}^{J} \left(\frac{\hat{w}_n}{\hat{P}^k_{I,n}} \right)^{-\beta^{k,j}_n} \right]^{-\theta}.$$

This can be rearranged to the following:

$$\frac{\hat{w}_n}{\hat{P}^j_{F,n}} = \hat{\pi}^j_{F,nn}{}^{\frac{-1}{\theta}} \left[\prod_{k=1}^{J} \left(\frac{\hat{w}_n}{\hat{P}^k_{I,n}} \right)^{\beta^{k,j}_n} \right].$$

Substituting the expression from (16) into this expression yields the following:

$$\frac{\hat{w}_n}{\hat{P}^j_{F,n}} = \hat{\pi}^j_{F,nn}{}^{\frac{-1}{\theta}} \left[\prod_{k,j=1}^{J} \hat{\pi}^j_{I,nn}{}^{\frac{-\beta^{k,j}_n}{\left(I-\beta^{k,j}_n\right)\theta}} \right].$$

Finally, an expression for change in welfare can be found by substituting the expression above into (13):

$$\hat{W}^{VS}_n = \prod_{j=1}^{J} \left(\hat{\pi}^j_{F,nn}{}^{\frac{-1}{\theta}} \left[\prod_{k,j=1}^{J} \hat{\pi}^j_{I,nn}{}^{\frac{-\beta^{k,j}_n}{\left(I-\beta^{k,j}_n\right)\theta}} \right] \right)^{\alpha^j_n}$$

The GFT under the current regime can be represented as the change in welfare going from the current regime with observed measures of $\pi^j_{F,nn}$ and $\pi^j_{I,nn}$ to a counterfactual regime where trade is fully inhibited so that $\acute{\pi}^j_{F,nn} = \acute{\pi}^j_{I,nn} = 1$, which can be represented as the following:

$$GFT^{VS}_n = \frac{1}{\hat{W}^{VS}_n} - 1 = \prod_{j=1}^{J} \left(\pi^j_{F,nn}{}^{\frac{-1}{\theta}} \left[\prod_{k,j=1}^{J} \pi^j_{I,nn}{}^{\frac{-\beta^{k,j}_n}{\left(I-\beta^{k,j}_n\right)\theta}} \right] \right)^{\alpha^j_n} - 1. \qquad (17)$$

Models that employ the RP structure, like Caliendo and Parro (2015), assume that $\hat{\pi}^j_{F,nn} = \hat{\pi}^j_{I,nn} = \hat{\pi}^j_{nn}$ for all n and j, which yields the following more simple expression for the GFT:

$$GFT^{RP}_n = \prod_{k,j=1}^{J} \left(\pi^j_{nn}{}^{\frac{-1}{\left(I-\beta^{k,j}_n\right)\theta}} \right)^{\alpha^j_n} - 1. \qquad (18)$$

In cases where $\pi^j_{F,nn} = \pi^j_{I,nn} = \pi^j_{nn}$, equations (17) and (18) are equivalent.

2.5.1 Vertical Specialization: An Illustration with One Sector

To provide an intuitive illustration of the GFT due to VS in this model, I consider a simple case where $J = 1$, countries are of equal size, and trade is fully uninhibited so that $\kappa_{s,ni} = 1$ for all n, i and s. From the trade share expression in (8), we can express the home expenditure for final products relative to that for intermediate products as:

$$\frac{\pi_{F,nn}}{\pi_{I,nn}} = \frac{T_{F,n}}{T_{I,n}} \frac{\phi_{I,n}}{\phi_{F,n}} = \frac{T_{F,n}}{T_{I,n}} \frac{\left(\sum_{i=1}^{N} T_{I,i} \left[c_i\right]^{-\theta}\right)}{\left(\sum_{i=1}^{N} T_{F,i} \left[c_i\right]^{-\theta}\right)}. \tag{19}$$

Since the structural difference between this model and the standard model with RP comes entirely from the wedge between $T_{F,n}$ and $T_{I,n}$, this wedge also drives VS in the model (that is, the wedge between $\pi_{F,nn}$ and $\pi_{I,nn}$). We can conclude the following:

Proposition 1: $\frac{\pi_{F,nn}}{\pi_{I,nn}}$ ***is increasing in*** $\frac{T_{F,n}}{T_{I,n}}$

This proposition follows from (19), since the influence of $T_{F,n}$ and $T_{I,n}$ on the bracketed multilateral resistance terms is of second order compared with the direct impact on the $T_{F,n}/T_{I,n}$ term. This result is also intuitive. As a country's relative productivity in a given type of product increases, it will rely more on home production for that product, and import a relatively higher share of the other type of product.

Next we consider the impact of changes in $\pi_{F,nn}/\pi_{I,nn}$ on welfare in this simplified case. According to Proposition 1, this ratio rises as $\frac{T_{F,n}}{T_{I,n}}$ rises, which represents change in across-stage comparative advantage towards final products. Since there is only one sector, equation (17) simplifies to the following expression for the GFT under VS:

$$GFT_n^{VS} = \pi_{F,nn}{}^{\frac{-1}{\theta}} \pi_{I,nn}{}^{\frac{-\beta_n}{(1-\beta_n)\theta}} - 1.$$

Meanwhile, equation (18), which represents GFT for country n in the model with RP and no VS, becomes:

$$GFT_n^{RP} = \pi_{nn}{}^{\frac{-1}{(1-\beta_n)\theta}} - 1.$$

Clearly, GFT according to the equations above depend significantly on the magnitude of the intermediates share in production, β. We will consider three separate cases: $\beta = 0.5$, $\beta > 0.5$ and $\beta < 0.5$. For simplicity of exposition, I will assume that $\pi_{nn} = \left(\pi_{F,nn} + \pi_{I,nn}\right)/2$.

Proposition 2: ***When*** $\beta = 0.5$ ***and*** $\pi_{nn} = \left(\pi_{F,nn} + \pi_{I,nn}\right)/2$***, GFT under the VS model are greater or equal to GFT under the RP model for all countries.***

This proposition clearly follows from the GFT expressions above. If $\beta = 0.5$, then these expressions degenerate to the following:

$$GFT_n^{VS} = \pi_{F,nn}^{\frac{-1}{\theta}} \pi_{I,nn}^{\frac{-1}{\theta}} - 1, \quad GFT_n^{RP} = \pi_{nn}^{\frac{-2}{\theta}} - 1.$$

Since π_{nn} is equal to the average of $\pi_{F,nn}$ and $\pi_{I,nn}$, Proposition 2 is proven by Jensen's Inequality after taking the logarithm of the expressions above. Figure 2 illustrates this finding, where $\pi_{F,nn}/\pi_{I,nn}$ is depicted as rising, moving left to right.[8] At the midpoint, where $\pi_{F,nn}/\pi_{I,nn} = 1$, GFT are minimized for country n. This also represents the GFT according to the RP assumption that ignores differences between $\pi_{F,nn}$ and $\pi_{I,nn}$. Whether country n specializes in final product production, so that $\pi_{F,nn}/\pi_{I,nn} > 1$, or specializes in intermediate product production, so that $\pi_{F,nn}/\pi_{I,nn} < 1$, GFT rise in a symmetric way relative to the model with RP where $\pi_{F,nn}/\pi_{I,nn} = 1$.

This case reflects an important insight that is also provided by Melitz and Redding (2014). As the wedge between $\pi_{F,nn}$ and $\pi_{I,nn}$ increases to reflect a stronger pattern of comparative advantage across production stages (see Proposition 1), the GFT rise relative to a model that abstracts from this channel and makes the RP assumption. This illustrates how VS can lead to higher GFT.

We next consider cases where $\beta \neq 0.5$.

Proposition 3: ***When*** $\beta \neq 0.5$***,*** $\pi_{nn} = (\pi_{F,nn} + \pi_{I,nn})/2$ ***and*** $\pi_{I,nn} + \pi_{F,nn} = 1$***, GFT under the VS model are higher than GFT under the RP model for some countries, and lower for others.***[9]

Figure 3 depicts the cases when $\beta = 0.75$ and $\beta = 0.25$, compared with the baseline case where $\beta = 0.5$. This again depicts rising $\pi_{F,nn}/\pi_{I,nn}$ moving left to right. When $\beta = 0.75$, so that the intermediates share in production is relatively high, the gains from intermediate products trade are much higher than the gains from final products trade. This is depicted by the green line in the figure, where GFT are higher to the right of the midpoint (where country n has a comparative advantage in final products) than to the left. In contrast, when $\beta = 0.25$ so that the intermediates share is very low, the opposite is true and the gains from final products trade are much higher than the gains from intermediate products trade. This is depicted by the red line in the figure, where GFT are higher to the left of the midpoint (where country n has a comparative advantage in intermediate products) than to the right.

[8] Figures 2 and 3 depict GFT where $\theta = 8.26$ as in Eaton and Kortum (2002).

[9] When $\beta = 0.5$, $\pi_{I,nn} + \pi_{F,nn} = 1$ is a result from the model since wages are equal across countries. When $\beta \neq 0.5$, this is no longer necessarily the case. Meanwhile, the GFT expressions are correct, and hence the results in Section 4 hold, regardless of whether we impose the assumptions that $\pi_{nn} = (\pi_{F,nn} + \pi_{I,nn})/2$ and $\pi_{I,nn} + \pi_{F,nn} = 1$.

These cases reflect an interesting tension in this model. On the one hand, MSP implies an infinite number of intermediate stages and, hence, the GFT in intermediates are potentially very large. On the other hand, the benefits of trade in intermediates are discounted significantly if the intermediates share in production, β, is low. Both of these factors are somewhat captured in standard models with MSP that assume RP, although the inequality in GFT across countries due to VS is not captured.[10]

Returning to the example in Figure 3, it can be generally stated that, when $\beta > 0.5$, the minimum point of GFT for n is to the left of the midpoint and the maximum point is to the right of the midpoint. That is, the RP formula *overstates* the GFT for n if $\pi_{F,nn} < \pi_{I,nn}$ and *understates* the GFT if $\pi_{F,nn} > \pi_{I,nn}$. When $\beta < 0.5$, the opposite is true, as the minimum point of GFT for n is to the right of the midpoint and the maximum point is to the left of the midpoint. In that case, the RP formula *understates* the GFT for n if $\pi_{F,nn} < \pi_{I,nn}$ and *overstates* the GFT if $\pi_{F,nn} > \pi_{I,nn}$.

In the end, determining whether the GFT are higher in the VS model relative to the RP model depends on parameters in the data. Moreover, matching the model to data requires moving from a stylized one-sector model to a model with many sectors, which introduces intermediate input linkages across sectors. Although the wedge between $\pi_{F,nn}$ and $\pi_{I,nn}$ might be large or small for a given country-sector pair, intermediate linkages across sectors could significantly change this, which will have consequences for the GFT due to VS.

In the next section, I discuss the data and summarize the parameter inputs for equations (17) and (18).

3 Data

3.1 Data Construction

The main data source for this exercise is the WIOD, which provides an integrated global IO matrix composed of 40 countries (in addition to one "rest-of-world" country) and 35 sectors from 1995 to 2011.[11] In this analysis, I focus on 34 countries (which includes a "rest-of-world" country) and 31 sectors (15 goods-based and 16 service-based), as consistent with Costinot and Rodriguez-Clare (2014) who use the same database.[12] A

[10] Melitz and Redding (2014) emphasize the importance of the first channel in potentially generating very large GFT, but do not focus on the role that β has in governing the size and distribution of GFT across countries.

[11] Sectors in the WIOD correspond to two-digit International Standard Industrial Classification (ISIC) Revision 2 groups.

[12] Costinot and Rodriguez (2014) do not explicitly state why they do not use all 40 countries and 35 sectors. However, upon observation is it clear that the disregarded countries and sectors often have

list of these countries and sectors is reported in Tables 4 and 3 respectively.

For each country, the global IO matrix includes one home and 33 bilateral IO matrices, one for each of the 33 trade partners. These bilateral IO matrices are built by combining product-level bilateral international trade data with product-by-sector national supply and use tables (SUT) for each country. The trade data are initially classified at the HS6 product level from UN Comtrade; from there, each product is assigned to a specific "use" category (intermediate, final or capital) based on the UN Broad Economic Categories (BEC) classification;[13] then, these traded products are aggregated up to classification of product by category (CPA) groups (of which there are 59 in the WIOD) to construct country-level bilateral expenditure shares of intermediate, final and capital products imports by CPA product group; these shares are then combined with national SUTs to produce international SUTs, from which the global IO matrix is constructed.[14]

This construction procedure is crucially different from the standard approach taken for constructing imported IO matrices, based on the import proportionality assumption. The import proportionality assumption takes as given that domestically produced and imported products are treated equally across the economy. As a result, the shares of imported intermediate and final products for a given CPA product group are assumed to be equal.[15] This assumption, while convenient and sometimes necessary because of data limitations, is clearly violated empirically for many product groups.[16] Moreover, such an assumption makes it impossible to identify VS. For these reasons, it is important to choose data that are constructed without assuming import proportionality across intermediate and final stages for this exercise.

Rather than directly using the global IO table provided by the WIOD, I derive import shares based on a separate global IO table constructed from the international SUTs provided by the WIOD website. This alternative approach is necessary in order to capture the share of imported *products* according to the spirit of the model.[17]

missing data.

[13]The HS6 classification includes over 5000 products, many of which correspond to a unique "use" category. In some cases, however, a given product is assigned to more than one group. In these cases, use shares are assigned.

[14]See Dietzenbacher et al. (2013) for more details about how the WIOD is constructed.

[15]Examples of projects that assume import proportionality include the Organisation for Economic Co-operation and Development (OECD) and Global Trade Analysis Project (GTAP). The WIOD does make a proportionality assumption *within* intermediate, final and capital products so that, for example, the share of total metal ore intermediate products that are used by the Machinery not elsewhere classified (NEC) sector is assumed to be the same for domestic- and foreign-produced basic metals.

[16]See Dietzenbacher et al. (2013) for examples.

[17]To understand why this adjustment is necessary, consider the example of the Australian Construction sector. The value of imported intermediate products supplied to that country by the Construction sector can be easily calculated from the WIOD global IO table by taking the total value of intermediate products supplied from this sector (and destined for Australia) net of products supplied by the domestic sector. However, this measure does not necessarily correspond to a consistent measure of *products* since the

The constructed WIOD data provide enough detail to derive five out of the six variables needed to compute country-level welfare according to equations (17) and (18). For measures of consumption shares α_n^j at the country-sector level, I use the sectoral sum of spending on final products, divided by this sum for all sectors in n. For sectoral shares of intermediate inputs used in production β_n^j and sector-by-sector intermediate inputs used in production $\beta_n^{k,j}$ for each producing country, I use the value of intermediate inputs used by a sector j from sector k in n, divided by the total output from sector j in n. Finally, total home expenditure shares $\pi_{s,nn}^j$ are derived by taking the sum of total spending minus imports, divided by total spending, for a given country-sector-type pair njs.

For values of the sectoral dispersion parameters θ, I assume common values of $\theta = 4.55$ across sectors based on the aggregate estimate derived from Caliendo and Parro (2015). Caliendo and Parro derive estimates for θ according to an Eaton and Kortum (2002) model, using tariff data from 1989-1995 across 15 countries (estimates are reported in Table 2).[18] Although the authors also estimate θ^j by sector, I assume common values of θ across sectors for the baseline analysis to focus on the impact of VS rather than the impact of cross-sectoral variation in θ^j.[19]

3.2 Data Features

Figure 1 provides a depiction of the correlation between derived home expenditure shares for intermediate $\pi_{I,nn}^j$ and final $\pi_{F,nn}^j$ products for each country-sector pair (among 34 countries and 31 sectors) for 2005.[20] As discussed in the introduction, the standard model that uses the RP assumption (e.g., Caliendo and Parro, 2015) assumes that these

product mix for a given sector differs across countries. For example, the product mix of the Australian Construction sector (which is reported by the WIOD in the Australian national SUT) is different from that of the same sector in Canada. As a result, a different set of products might be exported from the Canadian Construction sector than those produced by the Australian sector and, hence, the value of imports for a given product group cannot be derived from the WIOD global IO tables directly. Instead, I construct an alternative global IO table from the WIOD international SUTs, which reports bilateral imports according to the product mix produced by the domestic industry for each country. From this, bilateral shares of intermediate and final products can be calculated at the sector level based on a common set of products across countries, and home expenditure shares can be constructed.

[18] Caliendo and Parro (2015) develop a model that employs the RP assumption. This assumption does not theoretically affect estimates of θ^j, so using their estimates to derive GFT based on equation (17) is a valid approach.

[19] As a robustness exercise, I also calculated results for GFT where θ^j varies across sectors according to sectoral estimates from Caliendo and Parro (2015). These results are reported in Table 6 in the Appendix, based on values for θ^j reported in Table 2.

[20] Although the data span 1995-2011, I focus this analysis on 2005 data to capture a period that was both i) when VS was near its peak globally and ii) outside any interference from the 2008 global financial crisis. I also examined other years during this period, finding that the results provided throughout this analysis are essentially robust from 1995 to 2011.

shares are equal, which corresponds to the 45-degree line in this figure. The scatter plot indicates that this assumption is clearly violated in the WIOD data, as there are many points that lie off the 45-degree line, indicating VS. This shows that there is a clear reason to be skeptical of the accuracy of the RP assumption based on these data.

Table 1 provides summary statistics for the variables α_n^j, π_{nn}^j, $\pi_{I,nn}^j$ and $\pi_{F,nn}^j$ and β_n^j for 2005. This table includes data from all 34 countries, and summarizes values both for all 31 sectors and for the 15 tradable non-service sectors (T) only. As the table indicates, the average overall share of intermediates used in production is approximately 0.53; for tradable products, this share is higher, at 0.63. The average country also imports a slightly higher share of intermediate than final products, indicated by the fact that average $\pi_{I,nn}^j$ is lower than average $\pi_{F,nn}^j$ both for all sectors and tradable sectors only.

Values in Table 1 are, however, misleading in that summary statistics mask much of the heterogeneity in VS observed across countries and sectors in Figure 1. The extent to which this heterogeneity has a significant impact on GFT depends on whether this pattern is heterogeneous within or across countries. Intuitively, if most countries tend to vary from upstream to downstream producers depending on the sector, then the impact of VS on GFT could tend to even out at the country level. On the other hand, if some countries tend to specialize in upstream or downstream production for all industries, then the impact on GFT could be substantial, and substantially different across countries. In addition, if some sectors have a particularly dramatic pattern of VS, and these same sectors tend to have higher consumption shares, then the impact of VS on GFT will be all the more significant.

To provide an indication of cross-sector heterogeneity, Table 3 displays a $count_n$ variable that depicts, for each sector, the number of countries (out of 34) that are specialized in the final stage of production. In other words, this variable provides a sense of whether VS is driven by technological factors that vary across countries, or factors that tend to be similar across countries for a given sector. From column 5, it is clear that many sectors feature a similar pattern across countries. For service-based sectors, nearly all countries import a higher share of intermediate than final products, and are hence downstream in the production process.[21] This is also the case for more resource-based sectors like Mining and Quarrying and Basic Metals. This is not surprising, since intermediate products in these sectors tend to be geographically clustered, and need to be heavily imported by most countries.

Meanwhile, there are several manufacturing sectors that feature $count_n$ close to 17, which indicates that the split between upstreamness and downstreamness is even across

[21] Note that service sectors are largely non-traded, as indicated by home expenditure shares that are close to one for both intermediate and final products in most cases.

countries. This identifies cases where VS due to cross-country differences is an important feature of international trade and includes sectors that are typically associated with VS, such as Electrical and Optical Equipment, and Transport. The extent to which this pattern affects GFT depends on how this pattern is reflected at the country level.

To provide an indication of cross-country heterogeneity, Table 3 provides a $count_j$ variable that indicates, for each country, the number of goods sectors (out of 15) in which that country specialized in the final stage of production. Korea is an outlier in that it is specialized in intermediate inputs production in more sectors than any other country, indicating this country's role as an upstream supplier in Asian global value chains (GVCs). The United States is also relatively specialized in intermediate inputs, indicating its upstream role in North American GVCs. At the other extreme, Mexico specializes in the final stage of production for all tradable sectors. This indicates Mexico's role as a final assembly hub for North American GVCs. Meanwhile, the majority of countries have $count_j$ values lying between 6 and 10, which indicates that countries are diversified across sectors and hence the impact of VS on country-level GFT could be moderate in most cases.

A final factor that could have an important influence here is intermediate input linkages across sectors. As discussed in Section 2, intermediate linkages could increase or decrease the impact of VS on GFT depending on the patterns that come out in the data. For example, if input linkages show that intermediates from sectors with higher import penetration are used by sectors with lower intermediate input shares (e.g., service-based sectors), then the impact of VS on GFT could be lower once linkages are included in the analysis.

In the next section, I quantify the overall impact of all these factors on GFT.

4 Results

In the following section, I report results from two different model settings. In the first, I consider GFT according to the VS and RP models in a setting with multiple sectors but no intermediate input linkages across sectors. This setting is useful for illustrative purposes and provides intuition that is closely aligned with the illustration described in Section 2.5.1. Based on this exercise, I find that VS generates GFT that are substantially different from the gains implied by an RP model for some countries. Among these countries, several emerging economies that tend to specialize in final production benefit more, while countries that specialize in intermediate production tend to benefit less, under the VS model relative to the RP model.

I then consider a setting that includes intermediate input linkages according to evidence from WIOD tables. This setting is closest to the state of the art (e.g., Caliendo and Parro, 2015) and thus the better option from which to draw overall conclusions. I find that intermediate input linkages undo much of the impact that VS has on GFT according to the setting without linkages. As a result, I conclude that the GFT are empirically similar across the VS and RP models.[22]

4.1 No Linkages

Table 5 provides calculations for GFT according to the models described in Section 2 with $\theta = 4.55$ for all sectors. Columns 1 and 2 report GFT for each country under the setting without intermediate inputs linkages for the RP model and the VS model respectively.

On average, GFT are 2.4% higher under the VS model. This is a modest difference compared with other factors that affect GFT. For example, Costinot and Rodriguez-Clare (2014) show that going from a model with no MSP to a model with MSP under the RP assumption raises the average GFT by roughly 75%.[23]

However, in looking across countries it is clear that GFT are substantially different across these two models for some countries. For example, Denmark, Indonesia and India each have GFT that are over 20% higher under the VS model relative to the RP model. These countries tend to import a greater share of intermediate than final products for most sectors (and on average across all sectors), and therefore specialize in final products assembly (see Table 4). Since tradable products production tends to use a share of intermediate products that is above 0.5 (see Table 1), countries that specialize in downstream production benefit more under the VS model compared with the RP model, as suggested by the illustration described in Section 2.5.1 and Figure 3.[24]

Meanwhile, the United States experiences a fairly substantial decline in GFT, equal to -9.3%, in going from the RP to the VS model. Again, this follows from the illustration in Section 2.5.1. This country specializes in intermediate production, and thus imports

[22] In the Appendix, I consider these two cases in a setting where θ^j varies across sectors according to values estimated in Caliendo and Parro (2015). These results also suggest that differences in GFT between the two models are modest.

[23] In another example, Levchenko and Zhang (2014) find that GFT are, on average, 30% higher according to a model with multiple sectors relative to a model with one sector. These additional gains are interpreted by the authors as gains due to specialization across sectors. It is also clear from the WIOD data that cross-sector specialization is a more important feature of the data than VS. For example, the average standard deviation in import shares across tradable sectors is roughly 0.22 for 2005 among the countries examined here, whereas the average standard deviation across intermediate and final stages is only 0.10.

[24] Again, these extra benefits stem from the fact that GFT in intermediate inputs are magnified in proportion to the Leontief inverse factor, which reflects the important role of the IO loop for economic welfare.

a lower share of intermediate products than final products. Since tradable products tend to use a high share of intermediates, GFT are higher in intermediate products than in final products. As a result, GFT are lower under the VS model compared with the RP model for the United States, while the gains are higher for the two countries that trade with the United States and specialize in downstream production, China and Mexico.

In sum, GFT under the VS model are modest on average, but significantly different than those under the RP model for some countries. For countries that specialize in final production, GFT tend to be higher under the VS model; for countries that specialize in intermediate production, GFT tend to be lower. However, once linkages across sectors are accounted for, the impact of VS on the GFT declines noticeably even for these relatively impacted countries, as discussed in the next subsection.

4.2 With Linkages

Table 5 reports GFT under the setting with intermediate input linkages in columns 4 to 6. Columns 4 and 5 report GFT for each country under the RP model and the VS model respectively. On average, GFT are 2.2% higher under the VS model. This is very close to average from the previous setting without linkages, and again fairly modest.

Looking at the country level, the difference between the RP and VS models is again modest, particularly compared with the suggested impact for some countries from the previous setting without linkages (see column 6 compared with column 3). For example, including VS raises GFT for Denmark by only 3.6%, which is less than one-fifth of the impact implied under the setting without linkages (23.7%). In fact, for all countries examined, including VS in the model leads to an impact on GFT of less than 5%. This is small given that there were numerous countries that experienced increased GFT in excess of 10% under the setting without linkages.

The explanation for this divergence differs from country to country. In general, cases where GFT due to VS are large in column 3 can be explained by one or two sectors, where the wedge between $\pi^j_{F,nn}$ and $\pi^j_{I,nn}$ is large and consumption share is high. Once cross-sectoral linkages are included, the GFT due to VS are no longer driven by the wedge between $\pi^j_{F,nn}$ and $\pi^j_{I,nn}$ for a given sector, but rather the wedge between $\pi^j_{F,nn}$ and a weighted average of $\pi^j_{I,nn}$ across all input sectors. In the end, this latter wedge tends to be much smaller than the sector-specific wedge.

For example, consider the case of Denmark, which enjoys the highest GFT due to VS according to column 3. Much of this impact is because of the Coke, Refined Petroleum and Fuel sector, where $\pi^j_{F,nn}$ is much higher than $\pi^j_{I,nn}$ (0.55 versus 0.09). Since the intermediate inputs share is remarkably high in this sector at 0.95, this sector adds significantly to GFT associated with VS for this country. In fact, if we ignore the impact of this sector, then Denmark's GFT due to VS in column 3 falls to only 3.1% in the no linkages case, which is very close to the cross-country average. Looking at intermediate input linkages, this sector uses a very high share of intermediates from the Mining and Quarrying sector, where the home expenditure share is much higher at $\pi^j_{I,nn} = 0.69$. In the end, the weighted average of $\pi^j_{I,nn}$ across all source industries is much closer to (and, in fact, higher than) $\pi^j_{F,nn}$ for this sector, so the GFT due to VS are much lower under the model with input linkages.

A similar explanation applies to the Food and Beverages sector in India, the Chemicals sector in Indonesia, the Construction sector in China, and the Transportation sector in Mexico. In all these cases, $\pi^j_{F,nn}$ and $\pi^j_{I,nn}$ are substantially different at the sector level, explaining roughly half (or more than half) of the overall GFT associated with VS for each country. Once sectoral linkages are considered, the wedge between $\pi^j_{F,nn}$ and the weighted average of $\pi^j_{I,nn}$ across source industries is much lower, so the GFT due to VS decline.[25]

Overall, these results suggest that VS, while a salient feature in the data, does not generate substantial GFT above the gains suggested by standard models with intermediate products and the RP assumption. For some countries, there do appear to be significant gains before intermediate input linkages are included. Once these linkages are included, however, the calculated GFT due to VS decline to levels lower than 1% of GDP for all countries.

5 Conclusion

This paper has sought to explore the relationship, qualitatively and quantitatively, between VS and GFT. I derive a simple extension of the Eaton and Kortum (2002) model of trade that illustrates the gains from specialization across stages of production. This model yields a simple solution relating the GFT to the share of trade in both intermediate and final products and the share of intermediate inputs used in production.

The results provide several interesting insights. First, both in theory and practice, the gains from VS depend on specialization across countries, sectors and stages of production. In looking broadly across countries, most sectors use a share of intermediates in production that is above 0.5. This suggests that the gains from VS are potentially positive for downstream producers and negative for the upstream producers, relative to the baseline model that assumes RP.

[25] For Brazil, the Electrical and Optimal Equipment, and Hotels and Restaurant sectors together account for the majority of GFT associated with VS. Once sectoral linkages are included, the impact of these sectors dissipates.

To examine these insights empirically, I calculate the GFT using data for 34 countries and 31 sectors constructed from the 2005 WIOD.

I find that the GFT are fairly similar under the VS framework as in the standard model with RP. Although VS is a clear and salient feature of the data, its impact on country-level GFT is modest compared with traditional sources of GFT, such as MSP or specialization across sectors. Moreover, the potential gains from VS are significantly attenuated by intermediate input linkages across sectors. These results suggest that VS is not a significant source of "missing" GFT.

References

Acemoglu, D., V. M. Carvalho, A. Ozdaglar, and A. Tahbaz-Salehi (2012): "The Network Origins of Aggregate Fluctuations," *Econometrica*, 80, 1977–2016.

Acemoglu, D., A. Ozdaglar, and A. Tahbaz-Salehi (2015): "Microeconomic Origins of Macroeconomic Tail Risks," NBER Working Papers 20865, National Bureau of Economic Research, Inc.

Alvarez, F. and R. J. Lucas (2007): "General Equilibrium Analysis of the Eaton-Kortum Model of International Trade," *Journal of Monetary Economics*, 54, 1726–1768.

Antras, P. (2003): "Firms, Contracts, and Trade Structure," *The Quarterly Journal of Economics*, 118, 1375–1418.

Antras, P. and D. Chor (2013): "Organizing the Global Value Chain," *Econometrica*, 81, 2127–2204.

Antras, P., D. Chor, T. Fally, and R. Hillberry (2012): "Measuring the Upstreamness of Production and Trade Flows," *American Economic Review*, 102, 412–16.

Arkolakis, C., A. Costinot, and A. Rodriguez-Clare (2012): "New Trade Models, Same Old Gains?" *American Economic Review*, 102, 94–130.

Caliendo, L. and F. Parro (2015): "Estimates of the Trade and Welfare Effects of NAFTA," *Review of Economic Studies*, 82, 1–44.

Chor, D. (2010): "Unpacking Sources of Comparative Advantage: A Quantitative Approach," *Journal of International Economics*, 82, 152–167.

Costinot, A. and D. Donaldson (2012): "Ricardo's Theory of Comparative Advantage: Old Idea, New Evidence," *American Economic Review*, 102, 453–58.

Costinot, A., D. Donaldson, and I. Komunjer (2012): "What Goods Do Countries Trade? A Quantitative Exploration of Ricardo's Ideas," *Review of Economic Studies*, 79, 581–608.

Costinot, A. and A. Rodriguez-Clare (2014): *Trade Theory with Numbers: Quantifying the Consequences of Globalization*, Elsevier, vol. 4 of *Handbook of International Economics*, chap. 0, 197–261.

Costinot, A., J. Vogel, and S. Wang (2013): "An Elementary Theory of Global Supply Chains," *Review of Economic Studies*, 80, 109–144.

Dekle, R., J. Eaton, and S. Kortum (2007): "Unbalanced Trade," *American Economic Review*, 97, 351–355.

di Giovanni, J. and A. A. Levchenko (2010): "Putting the Parts Together: Trade, Vertical Linkages, and Business Cycle Comovement," *American Economic Journal: Macroeconomics*, 2, 95–124.

di Giovanni, J., A. A. Levchenko, and I. Mejean (2014): "Firms, Destinations, and Aggregate Fluctuations," *Econometrica*, 82, 1303–1340.

Dietzenbacher, E., B. Los, R. Stehrer, M. Timmer, and G. de Vries (2013): "The Construction Of World Input-Output Tables in the WIOD Project," *Economic Systems Research*, 25, 71–98.

Eaton, J. and S. Kortum (2002): "Technology, Geography, and Trade," *Econometrica*, 70, 1741–1779.

Fally, T. and R. Hillberry (2015): "A Coasian Model of International Production Chains," NBER Working Papers 21520, National Bureau of Economic Research, Inc.

French, S. (2016): "The Composition of Trade Flows and the Aggregate Effects of Trade Barriers," *Journal of International Economics*, 98, 114–137.

Hummels, D., J. Ishii, and K.-M. Yi (2001): "The Nature and Growth of Vertical Specialization in World Trade," *Journal of International Economics*, 54, 75–96.

Jones, C. I. (2011): "Intermediate Goods and Weak Links in the Theory of Economic Development," *American Economic Journal: Macroeconomics*, 3, 1–28.

Krugman, P. and A. J. Venables (1995): "Globalization and the Inequality of Nations," *The Quarterly Journal of Economics*, 110, 857–880.

Levchenko, A. A. and J. Zhang (2014): "Ricardian Productivity Differences and the Gains From Trade," *European Economic Review*, 65, 45–65.

Melitz, M. J. and S. J. Redding (2014): "Missing Gains From Trade?" *American Economic Review*, 104, 317–21.

Oberfield, E. (2014): "Misallocation in the Market for Inputs," Tech. rep.

Ossa, R. (2015): "Why Trade Matters After All," *Journal of International Economics*, 97, 266–277.

Yi, K.-M. (2003): "Can Vertical Specialization Explain the Growth of World Trade?" *Journal of Political Economy*, 111, 52–102.

——— (2010): "Can Multistage Production Explain the Home Bias in Trade?" *American Economic Review*, 100, 364–93.

6 Appendix: Tables and Figures

Table 1: Summary Statistics for 2005

	Mean	**Std. Dev.**	**Min.**	**Max.**	**N**
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
α_n^j	0.032	0.036	0	0.247	1054
π_{nn}^j	0.748	0.271	0.021	1	1054
$\pi_{I,nn}^j$	0.733	0.268	0.009	1	1054
$\pi_{F,nn}^j$	0.777	0.274	0.014	1	1054
β_n^j	0.532	0.163	0.055	0.956	1054
${\alpha_n^j}^T$	0.018	0.019	0	0.134	510
${\pi_{nn}^j}^T$	0.587	0.261	0.025	0.986	510
${\pi_{I,nn}^j}^T$	0.598	0.265	0.009	0.985	510
${\pi_{F,nn}^j}^T$	0.624	0.282	0.014	1	510
${\beta_n^j}^T$	0.631	0.115	0.119	0.956	510

Notes: Summary statistics described here are derived from the 2005 WIOD

Table 2: Dispersion Parameters for ISIC Rev. 2 Groups

	θ_{CP}	**Se.**	**Obs**
Sector	**(1)**	**(2)**	**(3)**
Agriculture	8.11	(1.86)	496
Mining	15.72	(2.76)	296
Food, Beverages and Tobacco	2.55	(0.61)	495
Textiles, Leather and Footwear	5.56	(1.14)	437
Wood and Wood Products	10.83	(2.53)	315
Paper, Paper Prod. and Printing	9.07	(1.69)	507
Coke, Petroleum, Nuclear	51.08	(18.05)	91
Chemical and Chemical Products	4.75	(1.77)	430
Rubber and Plastics	1.66	(1.41)	376
Non-Metallic Mineral Products	2.76	(1.43)	342
Basic and Fabricated Metals	7.99	(2.53)	388
Metal Products	4.30	(2.15)	404
Machinery, NEC	1.52	(1.81)	397
Electrical and Optical Equipment	10.60	(1.38)	343
Transport	0.37	(1.08)	245
Machinery, NEC Recycling	5.00	(0.92)	412
Average	4.55	(0.35)	7212

Notes: Statistics described here are derived from data provided in Caliendo and Parro (2015).

Table 3: Sectoral Level: Averages across Countries

	α_n^j	$\pi_{I,nn}$	$\pi_{F,nn}$	β_n	$count_n$
Sector	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Agriculture & Hunting	0.031	0.848	0.818	0.469	16
Mining & Quarrying	0.003	0.430	0.901	0.424	34
Food, Bev. & Tobacco	0.060	0.865	0.737	0.700	6
Textiles & Leath.	0.019	0.475	0.367	0.635	10
Wood & Prod.	0.001	0.727	0.857	0.645	30
Pulp & Publishing	0.009	0.739	0.814	0.619	26
Coke, Petro & Nuclear	0.013	0.612	0.688	0.727	24
Chemicals	0.018	0.419	0.429	0.664	22
Rubber & Plastics	0.004	0.589	0.592	0.656	19
Other Non-Metallics	0.003	0.783	0.820	0.597	20
Basic Metals	0.009	0.596	0.711	0.679	26
Machinery, NEC	0.027	0.482	0.380	0.646	9
Electrical & Optical	0.029	0.371	0.330	0.663	12
Transport	0.038	0.431	0.425	0.705	14
Manufacturing, NEC	0.012	0.600	0.491	0.632	8
Electricity, Gas & Water	0.018	0.923	0.963	0.542	22
Construction	0.120	0.965	0.995	0.590	30
Motor Sales	0.057	0.929	0.962	0.405	23
Retail Trade	0.040	0.981	0.981	0.370	16
Hotels & Restaurants	0.037	0.775	0.946	0.481	31
Inland Transport	0.022	0.903	0.944	0.474	28
Water Transport	0.002	0.572	0.646	0.597	28
Air Transport	0.004	0.543	0.610	0.628	24
Travel	0.010	0.812	0.916	0.507	27
Post & Telecom	0.017	0.923	0.972	0.430	34
Financial Intermediation	0.034	0.899	0.956	0.380	33
Real Estate	0.080	0.975	0.973	0.258	26
Renting	0.028	0.820	0.897	0.426	31
Education	0.051	0.859	0.996	0.221	32
Health and Social Work	0.073	0.953	0.997	0.366	31
Other Services	0.131	0.910	0.989	0.369	34
Average	0.032	0.733	0.777	0.532	23.4

Notes: Summary statistics described here are derived using data from the 2005 WIOD

Table 4: Country Level: Averages across Tradable Sectors

	$\pi_{I,nn}$	$\pi_{F,nn}$	$count_j$
Country	**(1)**	**(2)**	**(3)**
Korea	0.797	0.715	2
Australia	0.723	0.644	3
Finland	0.621	0.597	4
United States	0.789	0.739	4
Canada	0.582	0.516	5
Japan	0.852	0.759	5
Portugal	0.612	0.585	5
Czech Republic	0.535	0.511	6
Spain	0.691	0.615	6
Russia	0.799	0.737	6
Germany	0.567	0.576	7
France	0.622	0.641	7
Great Britain	0.582	0.583	7
Ireland	0.448	0.444	7
Austria	0.427	0.485	8
Belgium	0.282	0.337	8
Denmark	0.406	0.435	8
Hungary	0.466	0.552	8
Italy	0.731	0.769	8
Sweden	0.516	0.541	8
China	0.848	0.862	9
Netherlands	0.336	0.437	9
Slovakia	0.388	0.507	9
Slovenia	0.422	0.461	9
Taiwan	0.553	0.604	9
Greece	0.547	0.626	10
Indonesia	0.769	0.817	10
Poland	0.578	0.616	10
Turkey	0.680	0.783	11
Brazil	0.871	0.918	13
Romania	0.493	0.650	13
RoW	0.556	0.625	13
Indonesia	0.639	0.782	14
Mexico	0.592	0.745	15
Average	0.598	0.624	8.1

Notes: Summary statistics described here are derived using data from the 2005 WIOD

Table 5: Gains from Trade (% of GDP)

	RP, NL	**VS, NL**	**% Change**	**RP, L**	**VS, L**	**% Change**
Country	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Australia	7.8%	7.6%	-1.9%	6.1%	6.2%	1.8%
Austria	19.5%	19.8%	1.8%	16.5%	16.7%	1.5%
Belgium	25.7%	25.0%	-2.5%	21.0%	21.7%	3.4%
Brazil	3.3%	3.9%	17.5%	2.8%	2.8%	0.4%
Canada	13.7%	13.7%	-0.1%	10.6%	10.8%	1.8%
China	6.8%	8.0%	18.6%	7.2%	7.2%	-0.1%
Czech Republic	21.0%	20.7%	-1.5%	19.5%	19.9%	1.9%
Germany	12.1%	11.8%	-2.2%	9.7%	9.9%	1.1%
Denmark	21.3%	26.4%	23.7%	14.3%	14.8%	3.6%
Spain	9.7%	8.9%	-8.1%	9.1%	9.4%	2.8%
Finland	8.6%	8.7%	1.2%	9.4%	9.4%	0.5%
France	9.7%	9.4%	-3.2%	7.7%	7.9%	2.6%
Great Britain	9.8%	11.3%	15.1%	8.3%	8.5%	2.3%
Greece	10.0%	9.9%	-1.9%	9.8%	10.1%	3.1%
Hungary	23.4%	23.2%	-1.2%	21.5%	21.9%	1.6%
Indonesia	7.5%	9.0%	20.6%	8.6%	8.9%	3.1%
India	8.4%	10.0%	20.3%	7.1%	7.3%	3.0%
Ireland	18.5%	18.8%	1.4%	21.2%	21.8%	2.6%
Italy	7.6%	7.1%	-7.4%	7.0%	7.0%	1.1%
Japan	2.2%	2.1%	-5.4%	3.6%	3.7%	2.9%
Korea	5.4%	5.6%	4.0%	9.8%	10.0%	1.9%
Mexico	11.1%	12.3%	11.0%	8.6%	8.9%	3.7%
Netherlands	17.0%	16.6%	-2.2%	14.4%	14.7%	2.1%
Poland	13.2%	13.2%	0.0%	11.0%	11.2%	1.8%
Portugal	13.5%	13.0%	-4.1%	10.7%	10.8%	0.2%
Romania	12.6%	14.3%	12.7%	15.5%	15.9%	2.2%
Russia	9.7%	10.1%	4.7%	6.9%	6.9%	0.5%
Slovakia	26.8%	26.8%	-0.2%	24.7%	25.2%	2.1%
Slovenia	25.2%	24.7%	-2.1%	20.2%	20.4%	1.4%
Sweden	14.1%	13.6%	-3.4%	11.9%	12.0%	1.1%
Turkey	7.8%	7.7%	-1.8%	7.5%	7.7%	3.0%
Taiwan	17.2%	17.0%	-1.5%	16.2%	16.8%	4.0%
United States	4.2%	3.8%	-9.3%	3.9%	4.0%	1.5%
RoW	14.0%	14.9%	6.6%	13.6%	14.2%	4.3%
Average	12.9%	13.2%	2.4%	11.6%	11.9%	2.2%

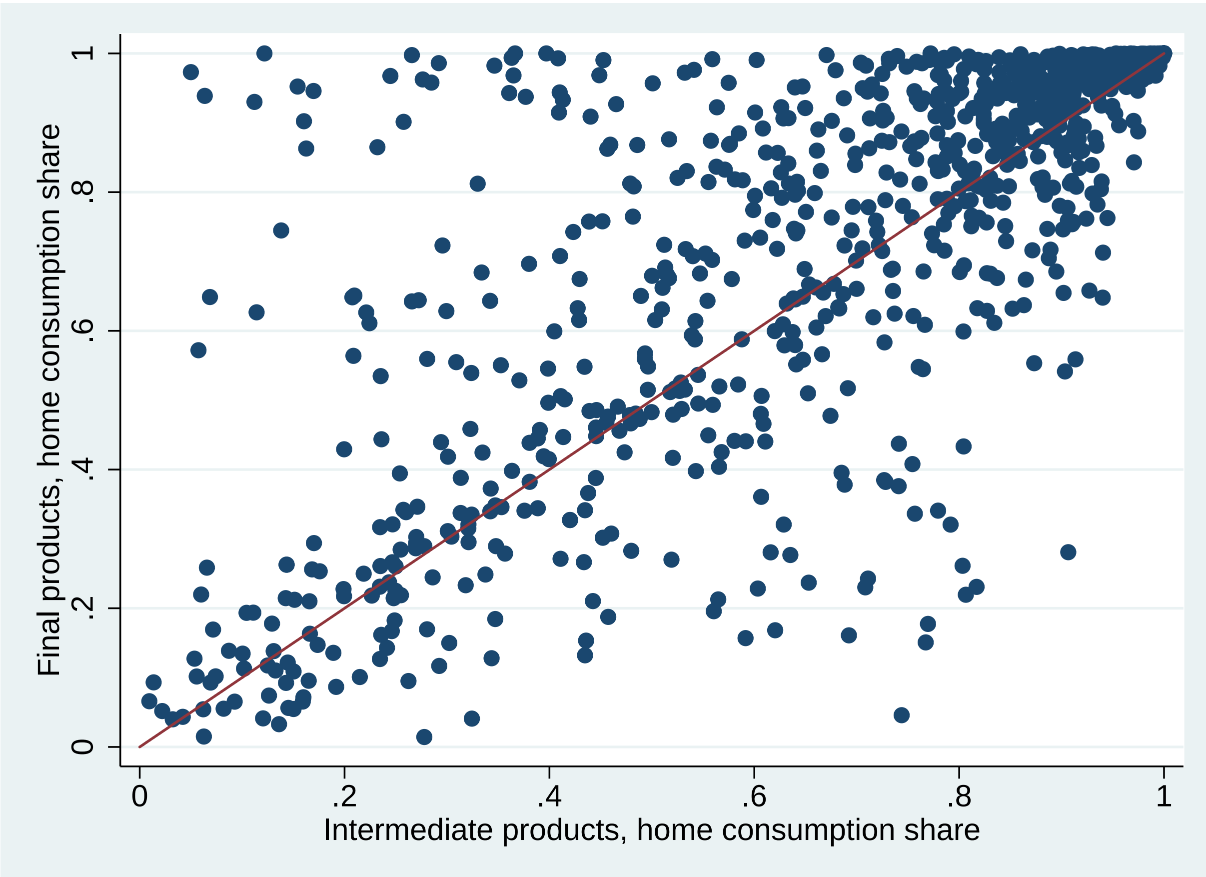
Notes: Results described here are in line with equations (17) and (18) derived using data from the 2005 WIOD combined with estimates of $\theta = 4.55$ from Caliendo and Parro (2015).

Table 6: Gains from Trade (% of GDP), Different θ^j

	RP, NL	**VS, NL**	**% Change**	**RP, L**	**VS, L**	**% Change**
Country	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Australia	25.9%	22.4%	-13.6%	16.0%	16.2%	1.6%
Austria	62.1%	63.1%	1.7%	42.9%	43.0%	0.2%
Belgium	73.6%	72.9%	-1.0%	49.7%	50.4%	1.3%
Brazil	8.7%	11.3%	30.0%	4.9%	4.8%	-1.0%
Canada	52.5%	51.9%	-1.2%	32.5%	32.8%	0.9%
China	12.3%	13.3%	7.5%	8.7%	8.7%	0.1%
Czech Republic	52.4%	51.7%	-1.2%	35.2%	35.8%	1.6%
Germany	33.2%	32.2%	-3.2%	19.8%	20.2%	1.7%
Denmark	53.4%	57.2%	7.1%	34.0%	34.6%	1.8%
Spain	38.6%	35.0%	-9.2%	23.6%	24.3%	3.0%
Finland	24.4%	25.5%	4.3%	17.9%	18.0%	0.6%
France	33.2%	32.5%	-2.1%	16.7%	17.0%	1.5%
Great Britain	30.9%	34.2%	10.6%	19.6%	19.9%	2.0%
Greece	36.2%	32.8%	-9.4%	24.5%	24.8%	1.4%
Hungary	62.9%	62.6%	-0.5%	41.6%	41.7%	0.2%
Indonesia	16.5%	18.3%	10.7%	15.3%	15.7%	2.3%
India	11.6%	14.4%	24.2%	7.3%	7.4%	2.3%
Ireland	50.3%	48.0%	-4.5%	40.7%	41.3%	1.4%
Italy	28.3%	25.3%	-10.5%	14.9%	15.0%	1.2%
Japan	3.9%	3.7%	-5.2%	3.4%	3.6%	5.5%
Korea	9.7%	9.3%	-4.0%	8.7%	9.2%	6.2%
Mexico	28.2%	34.8%	23.6%	19.3%	20.5%	6.3%
Netherlands	45.3%	43.2%	-4.5%	30.6%	31.9%	4.1%
Poland	41.8%	42.3%	1.0%	24.6%	24.9%	1.2%
Portugal	46.6%	45.8%	-1.6%	29.0%	29.0%	0.0%
Romania	32.1%	32.8%	2.3%	25.1%	25.3%	0.7%
Russia	39.1%	39.2%	0.3%	26.8%	26.8%	-0.1%
Slovakia	59.5%	59.4%	-0.3%	47.3%	47.5%	0.3%
Slovenia	79.7%	78.1%	-2.0%	48.8%	49.2%	0.8%
Sweden	33.6%	32.7%	-2.6%	23.5%	23.7%	0.9%
Turkey	29.6%	28.1%	-5.0%	18.8%	19.1%	1.2%
Taiwan	30.5%	30.2%	-1.2%	19.1%	20.1%	5.5%
United States	15.0%	13.6%	-9.0%	8.7%	8.7%	0.0%
RoW	40.4%	45.9%	13.6%	29.6%	32.0%	7.9%
Average	36.5%	36.6%	0.1%	24.4%	24.8%	1.7%

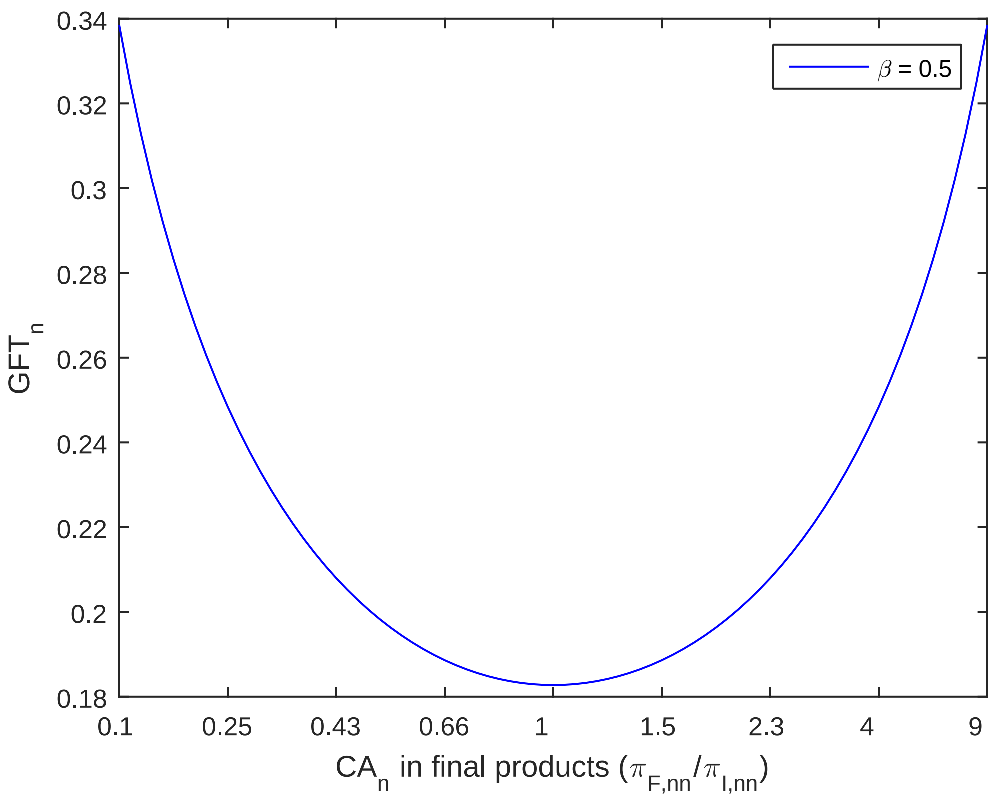
Notes: Results described here are in line with equations (17) and (18) derived using data from the 2005 WIOD combined with estimates of θ^j from Caliendo and Parro (2015).

Figure 1: WIOD Home Shares, 2005



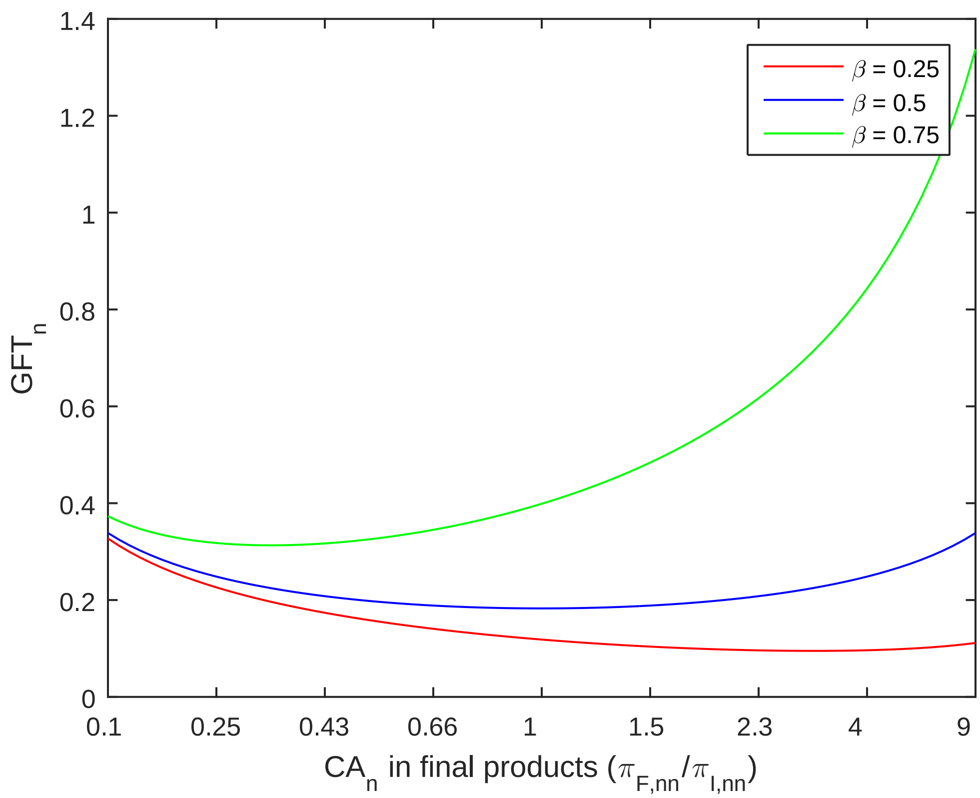
Notes: The figure depicts values of $\pi^j_{I,nn}$ and $\pi^j_{F,nn}$ on the horizontal and vertical axes respectively. The blue dots correspond to combinations derived from the WIOD data. The red line indicates the theoretical case where $\pi^j_{I,nn} = \pi^j_{F,nn}$, which corresponds to the assumed shares under the roundabout production environment.

Figure 2: Gains from Trade: $\beta = 0.5$



Notes: The GFT are calculated according to equation (17) in the simplified case where $J = 1$ and $\beta = 0.5$. The "CA_n in final products" variable on the horizontal axis corresponds to the ratio in equation (19). The midpoint of the figure represents the case without VS where GFT are equivalent under equations (17) and (18).

Figure 3: Gains from Trade: $\beta = 0.25, 0.5, 0.75$



Notes: The GFT are calculated according to equation (17) in the simplified case where $J = 1$ and $\beta = 0.25, 0.5, 0.75$. The "CA_n in final products" variable on the horizontal axis corresponds to the ratio in equation (19). The midpoint of the figure represents the case without VS where GFT are equivalent under equations (17) and (18).