Fragmentation and Gains from Trade[*]

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Abstract

In this paper, we estimate the competitiveness of countries in intermediate goods and in final goods. We find that China's competitiveness in both intermediate goods and final goods increased exceptionally rapidly during 1995-2011. We also find that the gains from trade of countries with strong comparative advantage in final goods can be substantially under-estimated if we do not separately take into account trade flows in intermediate goods and final goods. We also find that, during 1995-2011, the average increase in gains from intermediate goods trade across all countries in our sample is distinctly higher than the average increase in gains from final goods trade. This suggests that gains from trade due to international fragmentation of production is becoming more important over time relative to gains from trade in final goods.

JEL Classification codes: F10, F11, F14, F17

Keywords: fragmentation, gains in trade, global value chain, global sourcing,

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Fragmentation and Gains from Trade

1 Introduction

Production of goods is increasingly fragmented internationally. The intermediate goods used in the production of a final good in a country are often carried out in different countries. This phenomenon is variously termed fragmentation, vertical specialization, global sourcing, and so on. This has been documented and analyzed extensively in the literature, including the notable work of Hummels, Ishii and Yi (2001), Baldwin and Venables (2013), Costinot, Vogel and Wang (2013), Grossman and Rossi-Hansberg (2008), Johnson and Noguera (2012), Kee and Tang (2016), Koopman, Wang & Wei (2014), Antras and Gortari (2017), to name just a few. One implication of this phenomenon is that trade in intermediate goods accounts for a larger and larger fraction of total trade in the world. Therefore, in order to better understand the comparative advantage of countries and more accurately calculate their gains from trade, we must estimate the competitiveness of each country in intermediate goods and final goods separately as well as calculate the market share of home-supplied intermediate goods and final goods separately. The tradable intermediate goods (TIG) model is a convenient short cut to approximately account for trade flows in intermediate goods as part of total trade flows. However, it does not separately make use of the data of trade flows in intermediate goods and final goods. The TIG model assumes that, in any given market, a country's market share in final goods is the same as its market share in intermediate goods. Thus, a country's competitiveness in final goods is the same as that in intermediate goods. However, the existence of countries that serve as major assembly centers / export platforms that import intermediate goods for final assembly and export final goods to the rest of the world means that a country's competitiveness in exporting intermediate goods can be significantly different from that in exporting final goods. Therefore, in any given market, a country's market share in final goods can be substantially different from its market share in intermediate goods. Figure 1, which plots the market share of home-supplied intermediate goods and services of country n (π_{nn}) against the market share of home-supplied final goods in n ($\widetilde{\pi}_{nn}$), illustrate the above point clearly.[1] For example, for China, $\pi_{nn} \approx 0.61$ and $\widetilde{\pi}_{nn} \approx 0.91$, while for Great Britain, $\pi_{nn} \approx 0.68$ and $\widetilde{\pi}_{nn} \approx 0.48$. Such large variation in $\pi_{nn}/\widetilde{\pi}_{nn}$ across countries justifies our investigation into the above issues.[2] <Figure 1 is about here>

Arkolakis, Costinot and Rodriguez-Claire (2012) (hereinafter ACR) develop a formula that relates the gains from trade of a country to the expenditure share of home-supplied goods. The paper does not deal with the distinction between trade in intermediate goods and trade in final goods until the "Tradable Intermediate Goods Extension" section of the paper, where they adopt

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[1] Throughout this paper, "intermediate goods and services" are also called "intermediate goods" for short.

[2] The data for Figure 1 are derived from the TiVA data set as described in Appendix A.

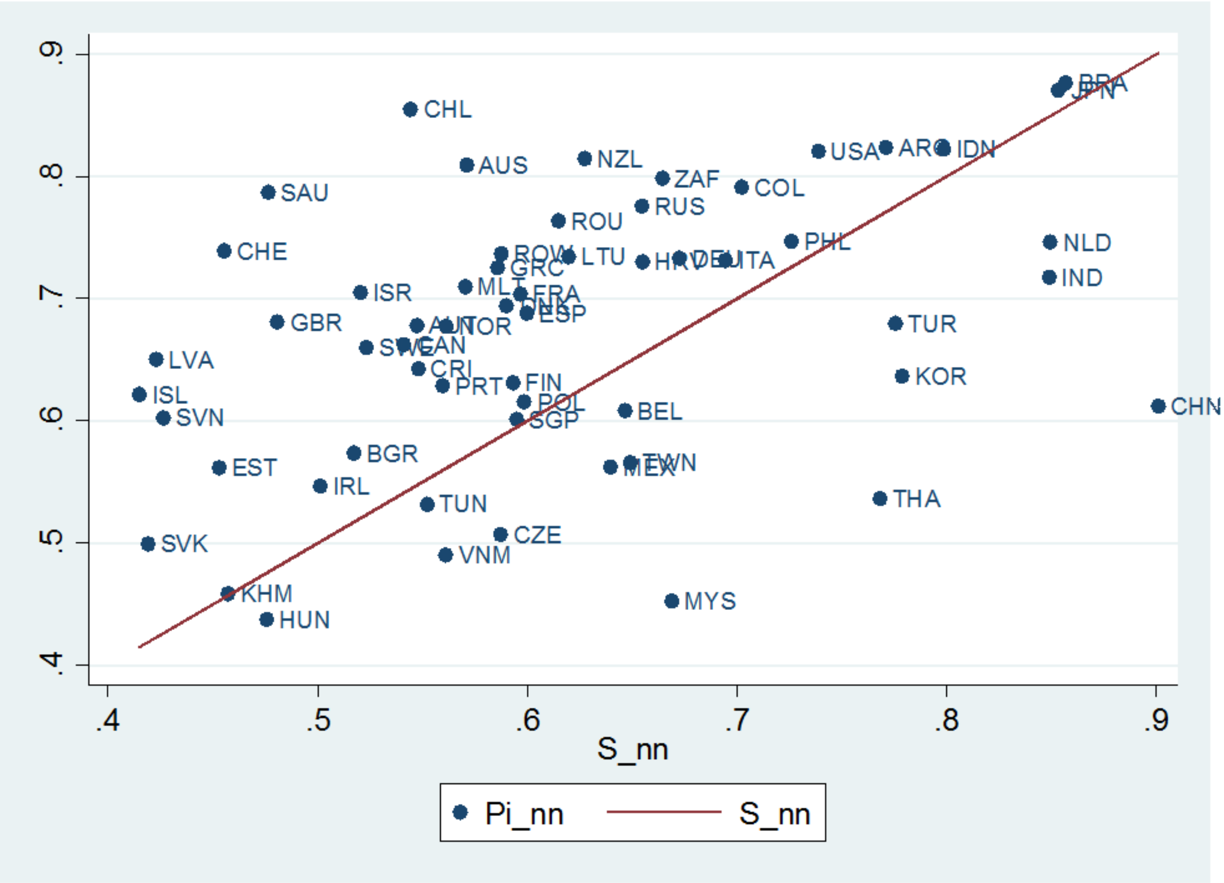

Figure 1: π_{nn}: Home share in intermediate goods (y-axis) vs. $\widetilde{\pi}_{nn}$: Home share in final goods (x-axis) as of 2011

the TIG approach to address the issue of intermediate goods trade. As we explained above, one shortcoming of the TIG approach is that the market share of home-supplied intermediate goods is assumed to be the same as that for final goods, which is not true in general. In this paper, we modify ACR's formula and make use of the data of home market shares in intermediate goods and final goods separately for calculating the overall gains from trade. Using our approach, the gains from trade in intermediate goods and final goods can be computed separately.

In this paper, we modify the TIG model of Eaton and Kortum (2002) (hereinafter referred to as the TIG model) and derive gravity equations for trade in intermediate goods and trade in final goods separately. Although the gravity equations in this paper are derived from the approach of Eaton and Kortum (2002) (hereinafter referred to as EK), they can be micro-founded by a more general model. As shown in Head and Mayer (2014), the gravity equation can be micro-founded from demand-side derivation, e.g. Armington (1969), or from supply-side derivation, e.g. EK or Chaney (2008) based on the Melitz (2003) approach. We also verify the generality of the gravity equations in this paper by deriving them from an alternative model (Armington) shown in Online Appendix G.1. Based on these gravity equations, we estimate countries' competitiveness in intermediate goods and in final goods. The levels of competitiveness of countries are estimated using the fixed-effect approach popularized by EK instead of the non-linear least squares estimation approach of Anderson and van Wincoop (2003). As argued in Head and Mayer (2014), the fixed-effect approach gives a consistent estimation of the general structural gravity equation, yet it has the advantage of imposing less structure in the estimation process.

We then go on to calculate the gains from trade of countries based on an equation that explicitly accounts for gains from trade in intermediate goods and in final goods separately. We then compare our gains from trade results with those obtained by using the TIG model, which does not account for trade in intermediate and final goods separately. We find that, across countries, the ratio of domestic market share in final goods ($\widetilde{\pi}_{nn}$) to that of intermediate goods (π_{nn}) is significantly and positively correlated with the ratio of competitiveness in final goods to that of intermediate goods. We argue that the countries with high $\widetilde{\pi}_{nn}/\pi_{nn}$ ratios have comparative advantage in final goods versus intermediate goods. This dimension of comparative advantage has not been captured by the TIG approach. It turns out that this dimension of comparative advantage is closely tied to where a country is positioned on the global value chain. As explained above, we find that a country that has comparative advantage in final goods tends to have a higher import penetration rate in intermediate goods relative to that in final goods. This further implies that it gains relatively more from trade in intermediate goods than trade in final goods. Most interestingly, its total gains from trade can be substantially under-estimated had we not separately accounted for these two components of gains from trade. The intuition for this result is that the structure of manufacturing production dictates that the gains from trade in intermediate goods are substantially larger than those from trade in final goods even for the same import penetration rate in both types of goods. The reason is as follows. The cost share of intermediate goods in manufacturing production (of both intermediate and final goods) is greater than 2/3 in most countries (which implies that the cost share of value-added is less than 1/3 in most countries). This implies that intermediate goods are very important in producing both intermediate and final goods. This in turn implies that the gains from trade in intermediate goods contributes substantially more than gains from trade in final goods to the overall gains from trade even if the import penetration rate in the two types of goods are the same.

Those countries that have strong comparative advantage in final goods gain significantly more from trade than other countries as they actively participate in the global value chain by importing a large share of intermediate goods (thus having high import penetration rate in intermediate goods), and then add factor inputs to produce final goods, which are mostly exported. They typically have much lower import penetration rates in final goods. One policy implication of this finding is that removing barriers to trade in intermediate goods contributes more to welfare than that in final goods, as for the same increase in import penetration rate for intermediate and final goods, the percentage increase in gains from trade generated from liberalization of intermediate goods trade is on average more than twice that from final goods trade. A real world example is the large volume of intermediate goods imported by China that helped to produce final goods cheaply both for domestic consumption and exporting (to pay for the imported intermediate goods). This helped to provide manufacturing employments and lift the living standards of tens of millions of Chinese citizens, signifying large gains from trade.

Our findings indicate that understanding this dimension of comparative advantage is very important in understanding the large gains from trade of many less developed countries that participate actively in the global value chain. It turns out that a large fraction of the gains from trade of these countries is attributed to trade in intermediate goods. The TIG approach tends to seriously underestimate the gains from trade of these countries, as explained above. In sum, we find that the degree of under-estimation of the gains from trade of a country by the TIG model increases with the strength of comparative advantage of the country in final goods versus intermediate goods.

We also find that, during 1995-2011, the average increase in gains from intermediate goods trade across all countries in our sample is distinctly higher than the average increase in gains from final goods trade. This suggests that gains from trade due to international fragmentation of production are becoming more important over time relative to gains from trade in final goods.

We begin our analysis with a one-sector model, on which sections 2, 3 and 4 are based. To check the robustness of our results, we carry out an extension based on a multi-sector setting with inter-sectoral input-output linkage. This extension is motivated in part by Costinot and Rodriguez-Clare (2014) and Caliendo and Parro (2015), both of whom calculate gains from trade based on a multi-sector setting with input-output linkage. We find that the most important results based on the one-sector setting are robust to the multi-sector extension.

We are not the first paper to estimate separate gravity equations for intermediate goods trade and final goods trade. One notable work is Baldwin and Taglioni (2013), who estimate trade elasticities for intermediate and final goods separately. But they are inconclusive about whether the two elasticities are significantly different. In this paper, we run the gravity regressions in order to establish that a country's competitiveness in final goods is in general different from that in intermediate goods. We find that when a country has higher competitiveness in final goods relative to that in intermediate goods, it tends to have higher gains from trade in intermediate goods relative to that in final goods, and higher overall gains from trade. Concerning the geography of the "upstreamness" of a country in the global value chain, Antras and Gortari (2017) predict that more centrally-located countries tend to produce goods with lower average "upstreamness". In this paper, stronger comparative advantage in final goods versus intermediate goods means greater specialization in the downstream (final) goods as opposed to the upstream (intermediate) goods, implying lower average "upstreamness". However, unlike Antras and Gortari (2017), we do not have a theory about the origin of this comparative advantage. ACR adopt the TIG approach to address the issue of intermediate goods trade in a later section of their paper. In this paper, we show that, in order to more accurately calculate the gains from trade, the formula has to be modified to make use of data on both home market shares in intermediate goods and in final goods if these data are available.

In Section 2, we present our model of fragmentation. In Section 3, we derive the gravity equations for trade in intermediate goods and trade in final goods based on our model. Estimating these equations yields the competitiveness of each country in intermediate goods and final goods in each year. We discuss the rapid rise in competitiveness of China in both intermediate goods and final goods during 1995-2011 and explain the underlying causes. In Section 4, we calculate the gains from trade of each country as of 2011, and the change in gains from trade during 1995-2011, by separately making use of data on home market shares in intermediate goods and final goods in each country. In section 5, we carry out a multi-sector extension of the one-sector model used in sections 2, 3 and 4. Section 6 concludes.

2 A Model of Fragmentation

In this section, we describe a model of production and trade of intermediate goods and final goods by extending the Ricardian model of EK. We use this model to derive and estimate two gravity equations. The gravity equations obtained, and the main results of this paper, however, are not dependent on this specific model. They can be derived from a more general model. In Online Appendix G.1, we describe how the same gravity equations can be obtained by an alternative approach, thus verifying the generality of the gravity equations that we estimate in the main body of this paper.

The Setting. There are N countries in the world, indexed by $n = 1, ..., N$. Country n has labor endowment L_n, which serves as the only primary input in production of all kinds of goods. Labor is fully mobile across sectors within the same country, but not mobile across countries. Labor wage in country n is denoted by w_n. The production of an intermediate or final good requires the conversion from a composite input called an input bundle, which is a combination of labor and the entire set of intermediate goods (which is called an composite intermediate good). There are multiple varieties of final goods and multiple varieties of intermediate goods. We assume that all countries have the capability to produce all varieties of intermediate goods and all varieties of final goods. All goods are tradeable but there are trade costs.

A typical country imports intermediate goods from all over the world (including itself), then combines the entire set of intermediate goods with domestic labor to form input bundles, and then produces either intermediate goods or final goods from the input bundles. The goods are then exported to destinations all over the world. In equilibrium, all countries export some intermediate goods and some final goods to all other countries and to themselves. Markets for both intermediate and final goods are assumed to be perfectly competitive.

Whenever an intermediate or final good is shipped from country n to country m, an iceberg trade cost τ_{mn} is incurred. That is, $\tau_{mn} > 1$ units of good are shipped from the origin for one unit to arrive at the destination. We assume $\tau_{nn} = 1$ for all n.

Preferences. In each country a representative household maximizes utility by choosing a consumption bundle of final goods, indexed in the interval [0, 1], subject to the budget constraint. The utility function of the representative household in country n is given by

$$U_n = \exp\left\{\int_0^1 \ln\left[\widetilde{Q}_n\left(i\right)\right] di\right\} \tag{1}$$

where $\widetilde{Q}_n\left(i\right)$ is the consumption of final good of variety i by the representative household in country n.

Technology and Comparative Advantage. For each country, each final good or intermediate good is converted from the input bundle, but the efficiency of conversion for each variety of good is stochastic. Denote the efficiency of country l in converting the input bundle into a final good of variety $i \in [0,1]$ by $\widetilde{Z}_l\left(i\right)$, and denote the efficiency for converting the input bundle into an intermediate good of variety $j \in [0,1]$ by $Z_l\left(j\right)$. The production function of an input bundle in country n is given by:

$$y_n = \left(M_n\right)^{1-\beta_n}\left(l_n\right)^{\beta_n}, \text{ where } 0 < \beta_n < 1, \tag{2}$$

where y_n is the quantity of input bundle produced in country n; M_n is the corresponding quantity of the composite intermediate good (which is defined in equation (3) below); l_n is the corresponding labor input.

Due to perfect competition, firms in country n will import the intermediate good of variety j with the lowest competitive price in n across all sources. The quantity of composite intermediate good produced by n is determined by the following function:

$$M_n = \exp\left\{\int_0^1 \ln\left[Q_n(j)\right] dj\right\}, \tag{3}$$

where $Q_n\left(j\right)$ is the quantity of intermediate good of variety j used by country n.

We follow EK by assuming that $Z_l\left(j\right)$ follows the Fréchet distribution, with the cumulative density function given by

$$\Pr[Z_l\left(j\right) < z] = e^{-[T_l]z^{-\theta}} \quad \forall j \in [0,1]$$

where T_l is country l's technology stock for producing intermediate goods and $1/\theta$ is positively related to the variance of the distribution of $Z_l\left(j\right) \forall j \in [0,1]$. When θ is smaller, there is more room for gains from trade due to differences in comparative advantage across varieties of intermediate goods among countries. The parameter T_l reflects country l's absolute advantage in producing intermediate goods, which can be viewed as a summary measure of the (broadly defined) technology stock of country l for the production of intermediate goods, e.g. technology embodied in machines, human capital, infrastructure, how well-developed is the domestic supply network, etc.

Following this, the competitive price of intermediate good of variety j exported from l to n is given by

$$p_{nl}\left(j\right)=\frac{c_l}{Z_l\left(j\right)}\tau_{nl}$$

where

$$c_l=\left(\frac{P_l}{1-\beta_l}\right)^{1-\beta_l}\left(\frac{w_l}{\beta_l}\right)^{\beta_l} \tag{4}$$

is the unit cost of an input bundle corresponding to equation (2), with P_l being the unit price of the composite intermediate good, the production function of which is given by equation (3). It can be easily shown that

$$P_n=\left(\Phi_n\right)^{-\frac{1}{\theta}}\,, \tag{5}$$

where

$$\Phi_n\equiv\textstyle\sum_{m=1}^{N}T_m\left(c_m\tau_{nm}\right)^{-\theta}$$

is defined as country n's global access to intermediate goods.[3]

It is straightforward to show that the market share of intermediate goods imported from country l in country n is given by

$$\pi_{nl}=\frac{T_l\left(c_l\tau_{nl}\right)^{-\theta}}{\Phi_n}=\frac{D_l\left(\tau_{nl}\right)^{-\theta}}{D_n+F_n} \tag{6}$$

where $D_l\equiv T_l\left(c_l\right)^{-\theta}=\left[T_l\cdot\left(\Phi_l\right)^{1-\beta_l}\left(w_l\right)^{-\beta_l\theta}\right]\left[\left(1-\beta_l\right)^{1-\beta_l}\left(\beta_l\right)^{\beta_l}\right]^{\theta}$ is defined as country l's competitiveness in supplying intermediate goods, and $F_n\equiv\sum_{m\neq n}D_m\left(\tau_{nm}\right)^{-\theta}$ is defined as country n's access to foreign intermediate goods. Thus, the competitiveness of a country in intermediate goods can be high because of three factors: low wage, large technology stock for the production of intermediate goods, or favorable access to foreign intermediate goods. Note that the set of unit costs of input bundles $\{c_l\}$ and set of unit prices of composite intermediate goods $\{P_l\}$ for $l=1,2,...N$ are interrelated through equations (4) and (5). When the set of trade-costs-adjusted technology stocks $\left\{T_m\left(\tau_{lm}\right)^{-\theta}\right|\,l,m=1,...,N\}$ and set of labor costs $\{w_m|\;m=1,...,N\}$ are known, we can solve for the $\{c_l|\;l=1,...,N\}$ and $\{P_l|\;l=1,...,N\}$ from the sets of equations given by (4) and (5).

We assume that $\widetilde{Z}_l\left(i\right)$ follows the Fréchet distribution, with the cumulative density function given by

$$\Pr[\widetilde{Z}_l\left(i\right)<z]=e^{-[\widetilde{T}_l]z^{-\widetilde{\theta}}}\quad\forall i\in[0,1]$$

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[3] Here we assume the elasticity of substitution between each pair of varieties of intermediate goods to be equal to one (the Cobb-Douglas case). If we assume a constant elasticity of substitution $\sigma'\neq 1$ instead, we will have the $P_n=\left[\Gamma\left(\frac{\theta+1-\sigma'}{\theta}\right)\right]^{\frac{1}{1-\sigma'}}\left(\Phi_n\right)^{-\frac{1}{\theta}}$ instead, as shown on p.1749 of EK. The same logic applies to final goods.

where $\widetilde{T}_l$ is country l's technology stock for producing final goods and $1/\widetilde{\theta}$ is positively related to the variance of the distribution of $\widetilde{Z}_l(i)$ $\forall i \in [0,1]$. Again, the parameter $\widetilde{T}_l$ reflects country l's absolute advantage in producing final goods, e.g. technology embodied in machines, human capital, infrastructure, how well-developed is the domestic supply network, etc.

The competitive price of final good of variety i that can potentially be exported from l to n is given by

$$\widetilde{p}_{nl}(i) = \frac{c_l}{\widetilde{Z}_l(i)}\tau_{nl},$$

where c_l is given in (4).

Similar to (6), the market share of final goods imported from country l in country n is given by

$$\widetilde{\pi}_{nl} = \frac{\widetilde{T}_l(c_l\tau_{nl})^{-\widetilde{\theta}}}{\widetilde{\Phi_n}} = \frac{\widetilde{D}_l(\tau_{nl})^{-\widetilde{\theta}}}{\widetilde{D}_n + \widetilde{F}_n} \tag{7}$$

where $\widetilde{\Phi_n} \equiv \sum_{m=1}^{N}\widetilde{T_m}(c_m\tau_{nm})^{-\widetilde{\theta}}$ is defined as country n's global access to final goods, $\widetilde{F}_n \equiv \sum_{m\neq n}\widetilde{D}_m(\tau_{nm})^{-\widetilde{\theta}}$ is defined as country n's access to foreign final goods, and $\widetilde{D_l} \equiv \widetilde{T}_l(c_l)^{-\widetilde{\theta}} = \left[\widetilde{T}_l\cdot(\Phi_l)^{1-\beta_l}(w_l)^{-\beta_l\widetilde{\theta}}\right]\left[(1-\beta_l)^{1-\beta_l}(\beta_l)^{\beta_l}\right]^{\widetilde{\theta}}$ is defined as the competitiveness of country l in supplying final goods. Since $\Phi_l = D_l + F_l$, a country is more competitive in final goods because of four factors: it has large technology stock for production of final goods, large technology stock for production of intermediate goods (as T_l raises D_l, which in turn raises Φ_l), low wage or favorable access to foreign intermediate goods.

It can be easily shown that the exact price index of the entire set of final goods as indicated in the utility function (1) is given by

$$\widetilde{P}_n = \left(\widetilde{\Phi_n}\right)^{-1/\widetilde{\theta}}. \tag{8}$$

Let us define country l's strength of comparative advantage in final goods versus intermediate goods as $\widetilde{T}_l/T_l$. Note that $\widetilde{T}_l/T_l = \widetilde{D_l}/D_l$ if $\theta = \widetilde{\theta}$. Thus, if θ is approximately equal to $\widetilde{\theta}$, then $\widetilde{T}_l/T_l$ is approximately equal to $\widetilde{D_l}/D_l$. Therefore, if country l has stronger comparative advantage in final goods versus intermediate goods, it also has larger $\widetilde{D_l}/D_l$.

3 Empirical Estimation

In this section, we use the data of global trade in both intermediate goods and final goods from the underlying inter-country input-output (ICIO) tables used in the construction of the Trade in Value Added (TiVA) data set to carry out estimation of the gravity equations for trade in intermediate goods and trade in final goods respectively. The data set is described in Appendix A.

3.1 Gravity Equation for trade in Intermediate Goods

One of our goals is to estimate the competitiveness of a country in exporting final goods and that in exporting intermediate goods. To do that, we turn to the gravity equation. The total value of intermediate goods exported from l to n is given by

$$X_{nl} = \pi_{nl} X_n \qquad \forall n, l = 1, ..., N \tag{9}$$

where X_n is country n's total expenditure on intermediate goods. Equations (6) and (9) imply that

$$\frac{X_{nl}}{X_{nn}} = \frac{\pi_{nl}}{\pi_{nn}} = \frac{D_l}{D_n} \tau_{nl}^{-\theta}$$

$$\Longrightarrow \qquad \ln \left(\frac{X_{nl}}{X_{nn}} \right) = \ln D_l - \ln D_n - \theta \ln \tau_{nl} \tag{10}$$

which we call the gravity equation for trade in intermediate goods. The parameter $\ln D_l$ is estimated as the coefficient for the indicator variable which takes on a value of 1 if country l is an exporting country and -1 if country l is an importing country and zero otherwise. To be consistent with the model, in the rest of the paper, whenever we estimate the competitiveness of countries based on country fixed effects, we impose the restriction that the importer fixed effect when a country is an importer is equal to the exporter fixed effect when the country is an exporter. We also impose the restriction that $\sum_{n=1}^{N} \ln D_n = 0$ so that the estimated competitiveness of each country is relative to the mean of all countries.[4] In estimating equation (10), we proxy the bilateral trade cost by

$$\ln \tau_{nl} = d_k + b + l + Legal + CU + Col + m_n, \tag{11}$$

a combination of commonly used bilateral trade cost measurements, including distance d_k, shared border b, shared language l, shared legal system $Legal$, shared currency CU, historical colonial linkage Col, and the overall destination fixed effect m_n. Here, as in EK, d_k is the distance effect between n and l lying in the kth interval, with the six intervals being [0, 375); [375, 750); [750, 1500); [1500 3000); [3000, 6000); and [6000, maximum) miles. The choice of the other right hand side variables is based on Head, Mayer and Ries (2010).

We then estimate Equation (10) using aggregated data for intermediate goods (from sixteen 2-digit manufacturing sectors) and services (from sixteen 2-digit service sectors) that are used to produce goods in the sixteen 2-digit manufacturing sectors, for each of the following seven years: 1995, 2000, 2005 and 2008-2011. These sectors are listed in Appendix A. Note that we have excluded all inputs from the primary sector (e.g. resources and agricultural goods) as intermediate goods when we calculate X_{nl} for running the regressions, but we include intermediate services for the production of manufactured goods. We report the result in Table 1. <Table 1 about here>

Table 1 shows that other than shared currency, all the coefficients have the expected sign in all years. When we use the logarithm of distance rather than the discrete distance measures for d_k and

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[4] This normalization is also adopted by EK.

Variable	1995	2000	2005	2008	2009	2010	2011
d_1	-4.06***	-3.94***	-3.77***	-3.62***	-3.74***	-3.73***	-3.75***
	(0.36)	(0.16)	(0.16)	(0.16)	(0.16)	(0.16)	(0.16)
d_2	-5.31***	-4.99***	-4.81***	-4.68***	-4.77***	-4.71***	-4.72***
	(0.36)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
d_3	-5.86***	-5.48***	-5.32***	-5.19***	-5.27***	-5.22***	-5.21***
	(0.35)	(0.11)	(0.101)	(0.11)	(0.11)	(0.11)	(0.11)
d_4	-6.28***	-5.81***	-5.65***	-5.54***	-5.60***	-5.57***	-5.54***
	(0.35)	(0.11)	(0.11)	(0.10)	(0.11)	(0.11)	(0.11)
d_5	-6.92***	-6.48***	-6.31***	-6.17***	-6.26***	-6.22***	-6.18***
	(0.36)	(0.12)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
d_6	-7.67***	-7.18***	-7.10***	-6.93***	-7.05***	-7.03***	-7.00***
	(0.35)	(0.11)	(0.11)	(0.10)	(0.11)	(0.11)	(0.10)
Shared Border	0.43***	0.44***	0.37***	0.33***	0.33***	0.32***	0.30***
	(0.076)	(0.073)	(0.073)	(0.071)	(0.072)	(0.072)	(0.071)
Shared Language	0.23***	0.24***	0.22***	0.19***	0.17***	0.18***	0.17***
	(0.052)	(0.049)	(0.049)	(0.048)	(0.049)	(0.049)	(0.048)
Shared Legal	0.36***	0.30***	0.26***	0.27***	0.28***	0.26***	0.24***
	(0.029)	(0.028)	(0.028)	(0.027)	(0.027)	(0.027)	(0.027)
Shared Currency	-0.35	-0.18**	-0.18***	-0.16**	-0.14**	-0.16**	-0.17***
	(0.34)	(0.072)	(0.068)	(0.066)	(0.067)	(0.067)	(0.066)
Colonial Linkage	0.40***	0.35***	0.34***	0.30***	0.34***	0.34***	0.36***
	(0.074)	(0.071)	(0.071)	(0.069)	(0.070)	(0.070)	(0.069)
Dest. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,595	3,600	3,600	3,600	3,600	3,600	3,600

*** indicates 1% significance level, ** indicates 5% significance level

Table 1: Gravity Equation for trade in Intermediate Goods and Services for Manufacturing Sectors

re-run Equation (10), we obtain Table 11, shown in Online Appendix G.2. The coefficients of the components of bilateral trade cost other than distance are quite similar there to the ones in Table 1. Table 2 shows the competitiveness in exporting intermediate goods as obtained in regression (10) subject to (11). <Table 2 about here>

Country	1995	Country	2005	Country	2011
USA	4.11	USA	3.79	USA	3.66
Japan	3.65	Japan	3.19	China	3.26
Germany	3.33	Germany	2.98	Germany	2.79
Italy	2.50	China	2.73	Japan	2.75
France	2.49	Korea	2.23	Russia	2.04
UK	2.46	Italy	2.20	Korea	2.03
Korea	2.37	UK	2.18	Italy	1.96
Taiwan	1.85	France	2.17	France	1.90
Russia	1.85	Russia	1.85	UK	1.90
Canada	1.70	Taiwan	1.66	India	1.67
Netherlands	1.61	Spain	1.43	Brazil	1.58
Switzerland	1.53	Canada	1.43	Canada	1.49
Sweden	1.50	Brazil	1.38	Spain	1.45
China	1.47	India	1.27	Taiwan	1.35
Spain	1.33	Netherlands	1.22	Australia	1.18

Table 2: Competitiveness in exporting Intermediate Goods and Services

3.2 Gravity Equation for Trade in Final Goods

The total value of exports of final goods from l to n is given by

$$\widetilde{X}_{nl} = \widetilde{\pi}_{nl}\widetilde{X}_n \quad \forall n, l = 1, ..., N \tag{12}$$

where $\widetilde{X}_n$ is the total expenditure of country n on final goods. Thus, (7) and (12) imply that

$$\frac{\widetilde{X}_{nl}}{\widetilde{X}_{nn}} = \frac{\widetilde{\pi}_{nl}}{\widetilde{\pi}_{nn}} = \frac{\widetilde{D}_l}{\widetilde{D}_n}\tau_{nl}^{-\widetilde{\theta}}$$

$$\implies \quad \ln\left(\frac{\widetilde{X}_{nl}}{\widetilde{X}_{nn}}\right) = \ln \widetilde{D}_l - \ln \widetilde{D}_n - \widetilde{\theta}\ln \tau_{nl} \tag{13}$$

which we call the gravity equation for trade in final goods. The parameter $\ln \widetilde{D}_l$ is estimated as the coefficients for the indicator variable which takes on a value of 1 if country l is an exporting country and -1 if country l is an importing country and zero otherwise; $\ln \tau_{nl}$ is given by (11). We report the estimation result for the regression of each year in Table 3. <Table 3 about here>

Variable	1995	2000	2005	2008	2009	2010	2011
d_1	-2.89***	-3.12***	-2.98***	-2.90***	-3.06***	-3.05***	-2.97***
	(0.69)	(0.28)	(0.27)	(0.26)	(0.26)	(0.26)	(0.25)
d_2	-4.73***	-4.68***	-4.48***	-4.41***	-4.52***	-4.47***	-4.38***
	(0.68)	(0.22)	(0.20)	(0.20)	(0.20)	(0.20)	(0.19)
d_3	-5.34***	-5.26***	-5.06***	-4.99***	-5.05***	-5.04***	-4.91***
	(0.67)	(0.19)	(0.18)	(0.17)	(0.17)	(0.18)	(0.17)
d_4	-5.90***	-5.74***	-5.58***	-5.52***	-5.54***	-5.49***	-5.38***
	(0.67)	(0.19)	(0.18)	(0.17)	(0.17)	(0.17)	(0.17)
d_5	-6.65***	-6.62***	-6.36***	-6.22***	-6.31***	-6.32***	-6.10***
	(0.68)	(0.20)	(0.19)	(0.18)	(0.18)	(0.18)	(0.18)
d_6	-7.77***	-7.65***	-7.41***	-7.30***	-7.38***	-7.40***	-7.20***
	(0.67)	(0.19)	(0.18)	(0.17)	(0.17)	(0.17)	(0.17)
Shared Border	0.31**	0.31**	0.28**	0.28**	0.30***	0.29**	0.30***
	(0.14)	(0.13)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
Shared Language	0.26***	0.34***	0.41***	0.32***	0.31***	0.35***	0.30***
	(0.098)	(0.085)	(0.082)	(0.079)	(0.078)	(0.079)	(0.078)
Shared Legal	0.52***	0.43***	0.36***	0.38***	0.42***	0.43***	0.40***
	(0.055)	(0.048)	(0.046)	(0.044)	(0.044)	(0.045)	(0.044)
Shared Currency	-0.26	-0.36***	-0.19*	-0.24**	-0.22**	-0.31***	-0.18
	(0.65)	(0.13)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Colonial Linkage	0.50***	0.42***	0.43***	0.38***	0.34***	0.35***	0.38***
	(0.14)	(0.12)	(0.12)	(0.11)	(0.11)	(0.11)	(0.11)
Dest. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,561	3,579	3,582	3,590	3,587	3,589	3,585
*** indicates 1% significance level, ** indicates 5% significance level,							
* indicates 10% significance level							

Table 3: Gravity Equation for Trade in Manufactured Final Goods (Equation (13))

There is nonlinearity in the distance effect, as shown in Tables 1 and 3. When the distance is small (d1 and d4, i.e. less than 3000 miles), distance is a higher barrier to trade in intermediate goods than to trade in final goods. But when the distance is large (d6, i.e. larger than 6000 miles), the reverse is true.

When we use the natural logarithm of distance rather the discrete distance measures and re-run Equation (13), we obtain Table 12, shown in Online Appendix G.2. In that table, the coefficients of the bilateral trade cost components other than distance and shared border are quite similar to the ones in Table 3.

Comparing Tables 11 and 12, we see that, on average, distance elasticity for trade in final goods (from Table 12) is larger than the distance elasticity for trade in intermediate goods (Table 11). That is, distance is a lower barrier to trade in intermediate goods than to trade in final goods. Baldwin and Taglioni (2013) found that distance elasticity is larger in magnitude when trade flow is dominated by intermediate goods, but then they found that the result is not robust.

From running Equation (13), we obtain the countries' competitiveness in supplying final goods. The results are given in Table 4. <Table 4 about here>

Country	1995	Country	2005	Country	2011
USA	4.64	USA	4.09	China	4.26
Japan	4.17	China	3.72	USA	4.02
Germany	3.74	Japan	3.54	Germany	3.25
Korea	3.16	Germany	3.37	Japan	3.04
Italy	3.00	Korea	2.94	Korea	2.85
UK	2.84	Italy	2.58	Italy	2.48
France	2.80	France	2.54	France	2.36
Taiwan	2.64	UK	2.16	UK	2.09
China	2.44	Taiwan	2.10	India	2.07
Sweden	1.99	Brazil	1.98	Taiwan	1.85
Canada	1.90	Thailand	1.79	Thailand	1.83
Thailand	1.88	Malaysia	1.74	Brazil	1.83
Singapore	1.80	Spain	1.70	Spain	1.63
Switzerland	1.78	Sweden	1.46	Malaysia	1.45
Netherlands	1.78	Canada	1.44	Canada	1.39

Table 4: Competitiveness in Exporting Final Goods

Comparing Tables 2 and 4, we see that a country's competitiveness (relative to the average) in intermediate goods and in final goods can differ significantly. For example, China's competitiveness in intermediate goods in 1995, 2005 and 2011 are 1.47, 2.73 and 3.26 respectively, while its final goods competitiveness are 2.44, 3.72 and 4.26 respectively. Thus, China was significantly more competitive in final goods compared with intermediate goods in those years. This result indicates that China has strong comparative advantage in final goods versus intermediate goods.

Comparative Advantage

Figure 2 shows that $\widetilde{D_l}/D_l$ is positively correlated with $\widetilde{\pi}_{ll}/\pi_{ll}$ for all country l. Thus, a country that has comparative advantage in final goods versus intermediate goods tends to have a high ratio of domestic share in final goods to domestic share in intermediate goods. This result makes sense. Intuitively, as a country that has comparative advantage in a set of goods should have a large domestic market share in those goods. In the context of our model, given that $\theta \approx \widetilde{\theta}$, $\widetilde{D_l}/D_l \propto \widetilde{\pi}_{ll}/\pi_{ll}$ across countries if $\widetilde{\Phi_l} \propto \Phi_l$ across countries, which turns out to be true.[5], [6] <Figure 2 about here>

3.3 China's Competitiveness

Comparing Tables 2 and 4, we see that the competitiveness of China in intermediate goods and final goods rose very rapidly during the period 1995-2011, while those of other highly competitive countries mostly fell continuously during this period. For example, the competitiveness of the US in intermediate goods in 1995, 2005 and 2011 are 4.64, 4.09 and 4.02 respectively, while its final goods competitiveness are 4.11, 3.79 and 3.66 respectively. The rise of China is one of the most important developments in international trade during this period. What explains the high competitiveness of China in the most recent year? What explains the rapid rise of competitiveness of China? The data indicates that the reason is the same for both intermediate goods and final goods competitiveness. Thus, we only focus on explaining intermediate goods competitiveness here and relegate the explanation concerning final goods to Online Appendix G.4. Recall that, in Section 2, we state that the competitiveness of a country in intermediate goods depends on three factors: wage, technology stock for intermediate goods, and access to foreign intermediate goods. Table 5 verifies empirically this theoretical prediction. The three factors together on average account for 94% of the intermediate goods competitiveness and 96% of the final goods competitiveness of a country. <Table 5 is about here>

The mean of each dependent and independent variable in Table 5 is normalized to zero.

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[5] See Figure 11 in Online Appendix G.3 for a plot of $\widetilde{\Phi}_n$ vs. Φ_n, which shows that $\widetilde{\Phi}_n$ is strongly correlated with Φ_n, with a correlation coefficient equal to 0.9715.

[6] The method of estimating T_n, Φ_n and F_n is as follows. First, note that π_{nn}, θ, w_n and β_n are either data or estimated elsewhere in the literature. Second, D_n is estimated from (10). This in turn allows us to estimate Φ_n from $\ln \Phi_n = \ln D_n - \ln \pi_{nn}$. Then we estimate P_n from $P_n = (\Phi_n)^{-\frac{1}{\theta}}$. This in turn allows us to estimate c_n from (4). Then we estimate T_n from $D_n = T_n (c_n)^{-\theta}$. We can estimate F_n from $1 - \pi_{nn} = F_n/\Phi_n$. The variables $\widetilde{T}_n$, $\widetilde{\Phi}_n$ and $\widetilde{F}_n$ are similarly estimated, using $\widetilde{\pi}_{nn}$, $\widetilde{\theta}$, w_n, β_n and equation (13). We use $\theta = \widetilde{\theta} = 4.0$, following Simonovska and Waugh (2014).

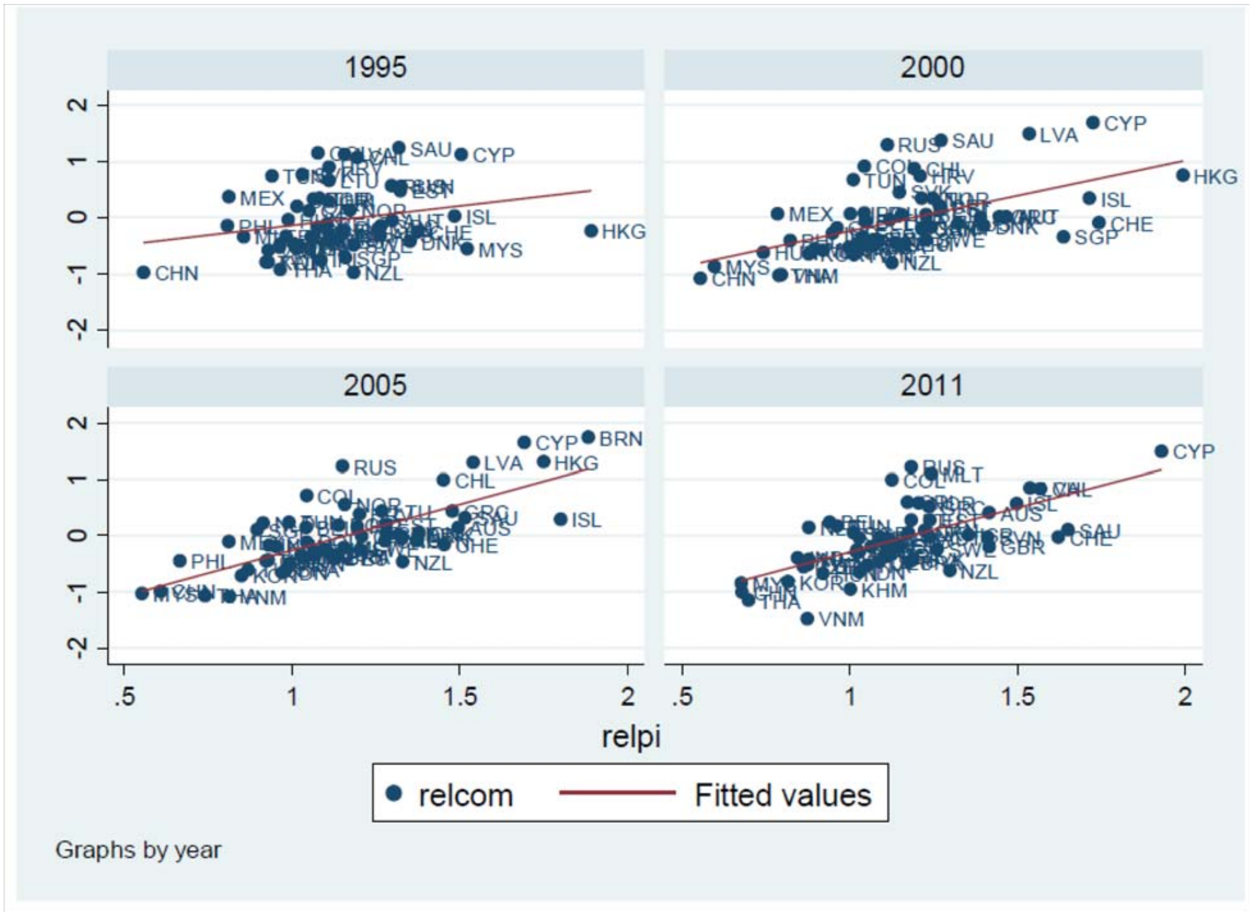

Figure 2: $\ln D_n - \ln \widetilde{D}_n$: ln (comp. in interm. goods/comp. in final goods) (y-axis) vs. $\pi_{nn}/\widetilde{\pi}_{nn}$: home share in interm. goods / home share in final goods (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

In the case of China, we want to find out the relative importance of each of these factors in determining the high competitiveness of China. We answer this question by referring to Figures 3, 4 and 5 concerning the competitiveness in intermediate goods. <Figures 3, 4, 5 about here>

In Figure 3, we see that there is a very strong and positive correlation between competitiveness in intermediate goods and access to foreign intermediate goods. Figure 4 shows that the correlation between intermediate goods competitiveness and technology stock in intermediate goods production is weaker than the correlation shown in Figure 3 though the correlation coefficient is still positive and significant. Figure 5 shows that the correlation between intermediate goods competitiveness and wage is statistically insignificant. We can understand China's rise by comparing it with the US. China is clearly an outlier in the plot of intermediate goods competitiveness against intermediate goods technology stock — its technology stock is much lower than that of the US during 1995-2011. On the other hand, its access to foreign intermediate goods rose rapidly from 1995 (much below that of the US) to 2011 (overtaking that of the US). Moreover, China's wage was much lower than

	Competitiveness in intermediate goods	Competitiveness in final goods
Technology Stock	0.905***	0.903***
	(0.048)	(0.032)
ln(wage)	-1.767***	-1.788***
	(0.101)	(0.064)
Access to foreign intermediate goods	0.419***	0.443***
	(0.034)	(0.032)
N	385	385
R^2	0.94	0.96

Table 5: Determinants of Competitiveness in Intermediate Goods and Final Goods

that of the US during 1995-2011, sustaining its high competitiveness. Based on these diagrams, we argue that the main factors that determine China's competitiveness are its favorable access to foreign intermediate goods and low wage, and not its technology stock. (The corresponding plots for final goods competitiveness are very similar. They are put in an Online Appendix G.4.) What explains the rise in China's access to foreign intermediate goods? We speculate that it is its large volume of processing trade (with very low trade costs in importing intermediate goods) and increasingly active participation in the global value chain during 1995-2011 (especially after accession to WTO in 2001), playing the role of a major global assembly center.

What explains China's rapid rise of competitiveness during 1995-2011 relative to other countries? As discussed above, China's competitiveness in 2011 (relative to other country's) is mainly due to its relatively favorable access to foreign intermediate goods and relatively low wage and not because of its technology stock, which is mediocre. Ironically, however, the *increase* in China's competitiveness from 1995 to 2011 in fact relied on a large part from the increase in its technology stock (even though its technology stock is still not that high compared with the US in 2011), while the increase in China's wage during this period in fact lowers its competitiveness. The increase in access to foreign intermediate goods (which was already quite high in 1995) only contributed modestly compared with technology stock in the increase in competitiveness of China during this period. This is shown in Table 6. <Table 6 about here>

Contribution of	ΔCompetitiveness in intermediate goods	ΔCompetitiveness in final goods
ΔTechnology Stock	156.2%	154.8%
Δln(wage)	-84.8%	-84.5%
ΔAccess to foreign intermediate goods	35.7%	37.1%

Table 6: The change in China's competitiveness from 1995 to 2011

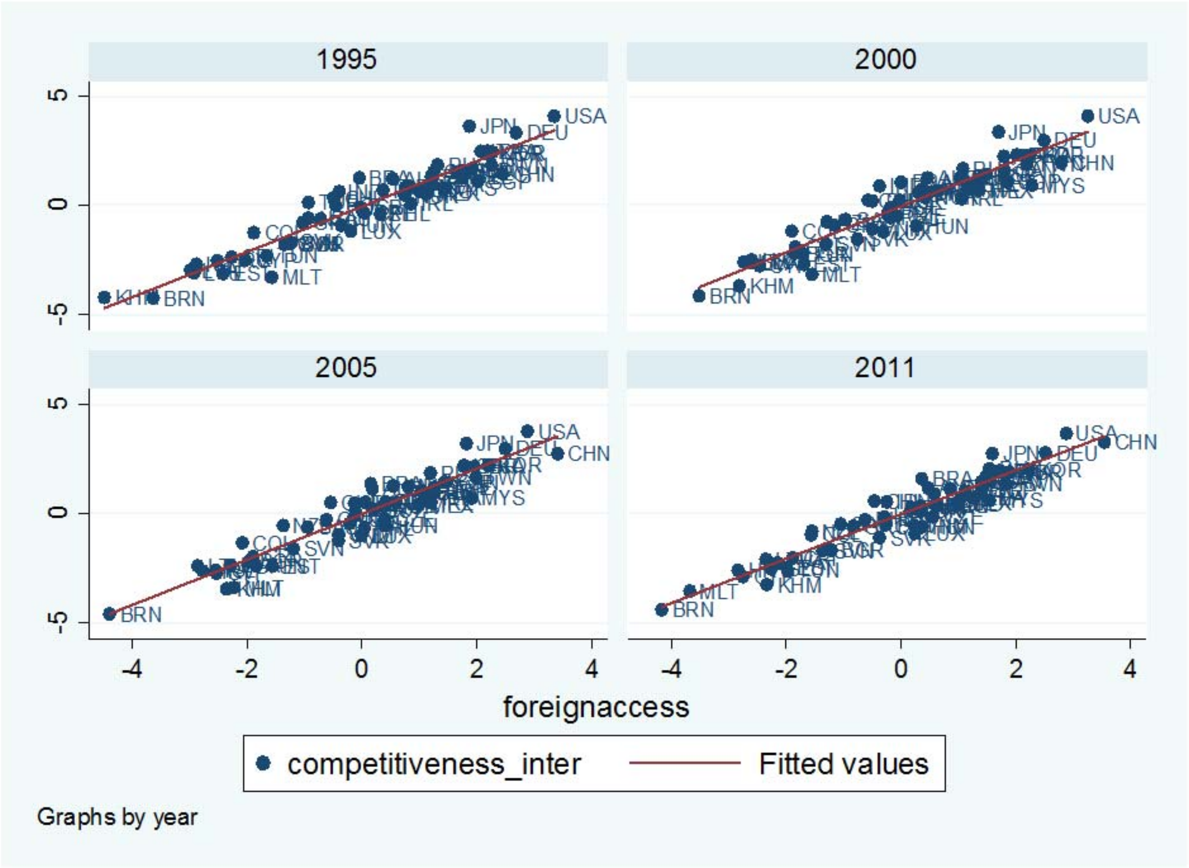

Figure 3: D_n: Comp. in interm. goods (y-axis) vs. F_n: Access to foreign interm. goods (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

The numbers in Table 6 are computed based on the regression coefficients in Table 5 and the change in China's technology stock, wage and access to foreign intermediate goods during 1995-2011.

4 Gains from Trade

In this section, we calculate the gains from trade of a country by making use of data on both home market shares in intermediate goods and final goods. Under our framework, we can separately calculate the gains from trade in final goods and intermediate goods. When a country imports more final goods, the consumers there can directly benefit from it through the cheaper imported goods. This is the source of the gains from trade in final goods. When a country imports more intermediate goods, the composite intermediate good becomes cheaper as cheaper imported intermediate goods (i) substitute for home-supplied ones and (ii) lower the costs of home-supplied ones by lowering the cost of the composite intermediate good through a multiplier effect. Thus, the domestic consumers

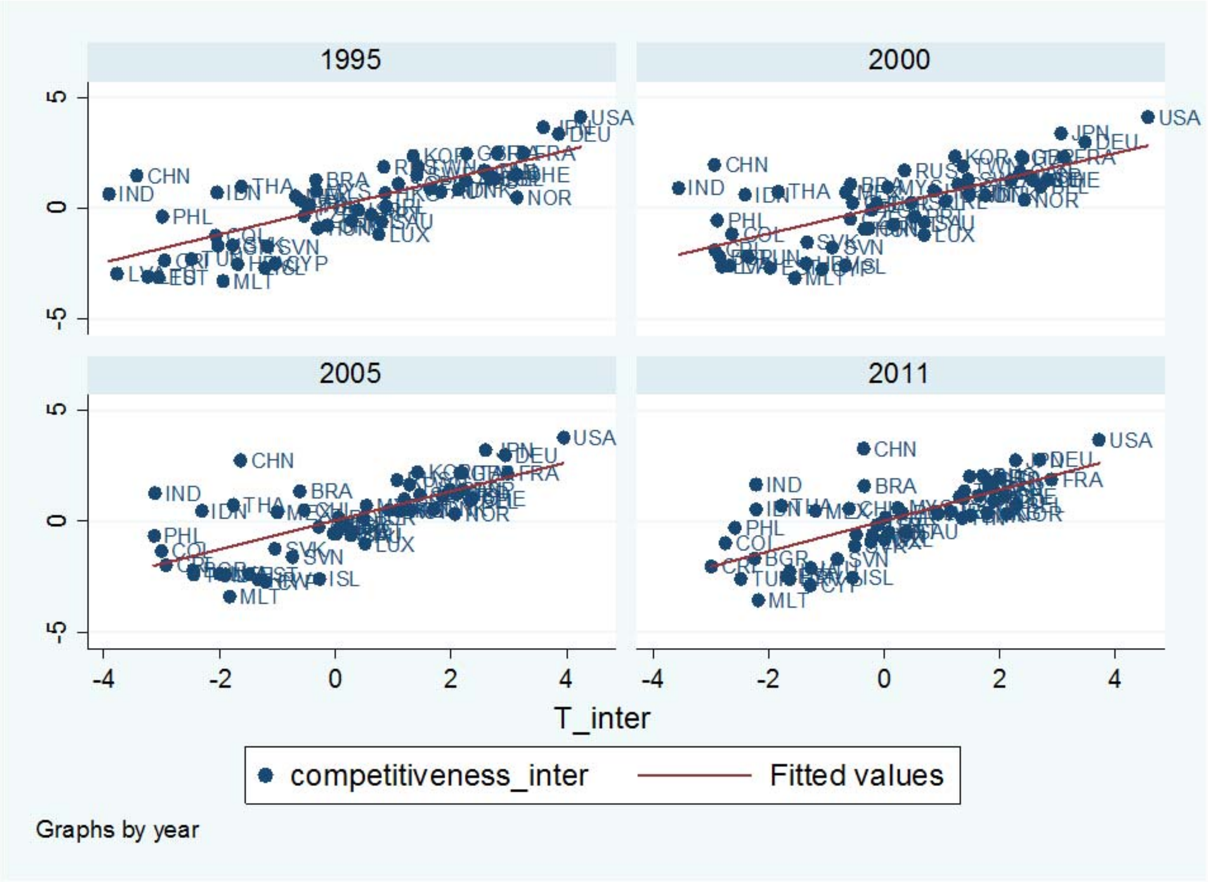

Figure 4: D_n: Comp. in interm. goods (y-axis) vs. T_n: Tech. stock in interm. goods (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

can indirectly benefit from it as a cheaper composite intermediate good in production implies cheaper final goods produced. This the source of the gains from trade in intermediate goods.

Let $\widehat{x} = x'/x$ (where x' is the new value and x is the old value) denote the change in the value of x. The welfare of country n, denoted by W_n, is equal to the real wage, $w_n/\widetilde{P_n}$. The following proposition would guide our welfare analysis in the rest of this section.

Proposition 1 *The change in welfare of country n can be expressed as*

$$\widehat{W_n} = \left(\widehat{\widetilde{\pi}_{nn}}\right)^{-1/\widetilde{\theta}} \left(\widehat{\pi_{nn}}\right)^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} \tag{14}$$

The gains from trade is defined as $\widehat{W_n} - 1$.

Proof:

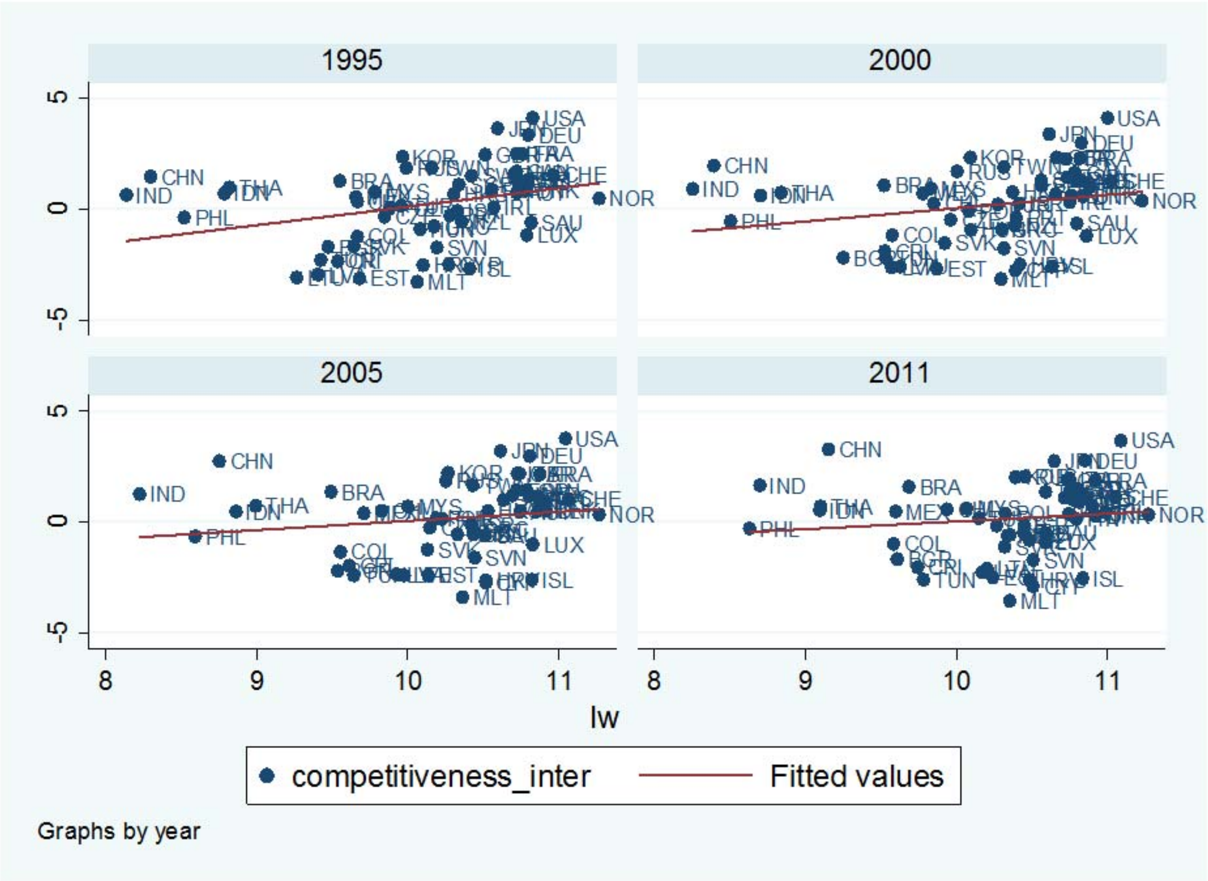

Figure 5: D_n: Comp. in interm. goods (y-axis) vs. $\ln w_n$: ln (wage) (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

According to (4) and (5), the percentage change in unit cost of the input bundle is given by

$$\begin{aligned} d\ln c_n &= \beta_n d\ln w_n + (1-\beta_n)\, d\ln P_n \\ &= \beta_n d\ln w_n - \left(\frac{1-\beta_n}{\theta}\right) d\ln \Phi_n . \end{aligned}$$

From this and (8), we obtain the percentage change in the welfare (i.e. real wage) of country n as

$$\begin{aligned} d\ln W_n = d\ln w_n - d\ln \widetilde{P_n} &= \frac{1}{\beta_n} d\ln c_n + \left(\frac{1-\beta_n}{\theta\beta_n}\right) d\ln \Phi_n + \left(\frac{1}{\widetilde{\theta}}\right) d\ln \widetilde{\Phi}_n \\ &= \left(\frac{1-\beta_n}{\theta\beta_n}\right)(\theta d\ln c_n + d\ln \Phi_n) + \left(\frac{1}{\widetilde{\theta}}\right)\left[\widetilde{\theta} d\ln c_n + d\ln \widetilde{\Phi}_n\right] \\ &= -\left(\frac{1}{\widetilde{\theta}}\right) d\ln \widetilde{\pi}_{nn} - \left(\frac{1-\beta_n}{\theta\beta_n}\right) d\ln \pi_{nn} \qquad (15) \end{aligned}$$

where the first term in the last line of (15) comes from

$$d\ln \widetilde{\pi}_{nn} = -\widetilde{\theta} d\ln c_n - d\ln \widetilde{\Phi}_n \text{ (based on (7))}$$

while the second term in the last line of (15) comes from

$$d\ln \pi_{nn} = -\theta d\ln c_n - d\ln \Phi_n \text{ (based on (6))}$$

Integrating equation (15) between the initial and new equilibria leads to (14). ■

4.1 Estimates of Gains from Trade

Denote welfare under autarky by W_n^A. Equation (14) implies that the gains from trade (starting from autarky) is given by

$$\widehat{W_n^A} - 1 \equiv \frac{W_n}{W_n^A} - 1 = (\widetilde{\pi}_{nn})^{-1/\widetilde{\theta}} (\pi_{nn})^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} - 1 \approx \underbrace{(\widetilde{\pi}_{nn})^{-1/\widetilde{\theta}} - 1}_{\substack{\text{gains from trade} \\ \text{in final goods}}} + \underbrace{(\pi_{nn})^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} - 1}_{\substack{\text{gains from trade in} \\ \text{intermediate goods}}} \quad (16)$$

when $[(\widetilde{\pi}_{nn})^{-1/\widetilde{\theta}} - 1][(\pi_{nn})^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} - 1]$ is sufficiently small, which would be true when $[(\widetilde{\pi}_{nn})^{-1/\widetilde{\theta}} - 1]$ or $[(\pi_{nn})^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} - 1]$ is sufficiently small, which holds for all the cases we consider in this paper.

We then compare it to the gains from trade based on the TIG model:

$$\frac{W_n}{W_n^A} - 1 = (\overline{\pi}_{nn})^{-1/(\overline{\theta}\beta_n)} - 1 \quad \text{with } \overline{\pi}_{nn} \equiv \frac{X_{nn} + \widetilde{X}_{nn}}{X_n + \widetilde{X}_n}$$

where $\overline{\pi}_{nn}$ and $\overline{\theta}$ are variables/parameters corresponding to the TIG model, which pools trade in intermediate and final goods together. There is no consensus in the literature concerning whether the trade elasticity in intermediate goods trade is different from that in final goods. Simonovska and Waugh (2014) estimate that the point estimate of the elasticity of trade should be around 4.0. Eaton and Kortum (2012) also adopt such a number. Therefore, following these authors, we assume that $\overline{\theta} = \theta = \widetilde{\theta} = 4.0$. The gains from trade in 2011 based on the our model and the TIG model respectively are shown in Table 8 in Appendix D.

Because we separately account for the gains from trade in intermediate goods and those from final goods, the level of gains from trade based on our model is in general different from that obtained from the TIG model, as long as $\widetilde{\pi}_{nn}$ is not equal to π_{nn}. According to the data, for about 80% of the observations, $\beta_n \leq 0.333$.[7] Hence, the following corollary holds for a vast majority of the observations in our sample.

Corollary 1 *As long as* $\beta_n \leq 0.333$ *(which is true of about 80% of the observations) and* $\overline{\theta} = \theta = \widetilde{\theta} = 4.0$ *(approximation based on the literature), the gains from trade of country n is underestimated by the TIG model if the ratio of the domestic share in final goods* ($\widetilde{\pi}_{nn}$) *to the domestic*

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[7] Out of 434 observations, only 94 have $\beta_n > 0.333$.

share in intermediate goods (π_{nn}) is great than one. The higher (lower) is this ratio ($\widetilde{\pi}_{nn}/\pi_{nn}$), the greater (smaller) is the degree of under-estimation.

Proof: See Appendix E.

The intuition that the TIG model under-estimates the overall gains from trade when $\widetilde{\pi}_{nn} > \pi_{nn}$ is that the gains from trade in intermediate goods are substantially larger than those from trade in final goods even when $\widetilde{\pi}_{nn} = \pi_{nn}$. The reason is that since $\beta_n \leq 0.333$ for about 80% of the observations, $1 - \beta_n$, the cost share of intermediate goods in manufacturing production, is very likely to be greater than 0.667 (with the rest being the cost share of factor inputs such as labor and capital) in any country, which implies that intermediate goods are very important in producing both intermediate and final goods. This in turns implies that any given import penetration rate in intermediate goods contributes substantially more to gains from trade than the same import penetration rate in final goods. Mathematically, referring to (16), given that $\theta = \widetilde{\theta} = 4.0$ and $\beta_n \leq 0.333$, we see that the exponent of π_{nn}, which is equal to $-\left(\frac{1-\beta_n}{\theta\beta_n}\right)$, is more than twice the magnitude of the exponent of $\widetilde{\pi}_{nn}$, which is equal to $-1/\widetilde{\theta}$. Thus, the gains from trade in intermediate goods carry a much higher weight than those from trade in final goods in determining the overall gains from trade. Therefore, if $\widetilde{\pi}_{nn}/\pi_{nn} > 1$ (import penetration rate of final goods is low and import penetration rate of intermediate goods is high) and one does not distinguish between intermediate goods and final goods in calculating the market share, the under-estimation of the gains from trade in intermediate goods would be so high as to lead to under-estimation of the overall gains from trade. Hence, $(\widetilde{\pi}_{nn})^{-1/\widetilde{\theta}} (\pi_{nn})^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)}$ would be greater than $(\overline{\pi}_{nn})^{-1/(\overline{\theta}\beta_n)}$.

Figures 6 and 7 verify Corollary 1. They show that countries with high $\widetilde{\pi}_{nn}/\pi_{nn}$ and $\widetilde{D_n}/D_n$ also tend to be those whose gains from trade are underestimated by the TIG model, and degree of under-estimation increases with $\widetilde{\pi}_{nn}/\pi_{nn}$ or $\widetilde{D_n}/D_n$, both of which measure the strength of comparative advantage of the country in final goods. In these diagrams, GFT_n^{TIG} / GFT_n^{LQ} denote the ratio of gains from trade based on the TIG model and those based on the model in this paper. Figure 6 shows that GFT_n^{TIG} / GFT_n^{LQ} is significantly and positively related to $\ln D_n - \ln \widetilde{D}_n$. Figure 7 shows that GFT_n^{TIG} / GFT_n^{LQ} is significantly and positively related to π_{nn} / $\widetilde{\pi}_{nn}$. <Figures 6 and 7 about here>

Table 7 gives the breakdown of total gains from trade into those from trade in intermediate goods and those from trade in final goods as of 2011. <Table 7 about here>

In fact, within the entire sample of countries, the average gains from trade in intermediate goods is 8.38% while the average gains from trade in final goods is 3.65%. Within the OECD (non-OECD) countries, they are 5.28% (10.21%) and 3.07% (3.99%) respectively. Thus, within the sample countries, the gains from trade in intermediate goods is more than twice of those from final

Country	Welfare		Country	Welfare		Country	Welfare	
	Interm. Goods	Final Goods		Interm. Goods	Final Goods		Interm. Goods	Final Goods
Argentina	3.02%	1.78%	Germany	4.68%	2.70%	Norway	4.50%	2.37%
Australia	1.95%	2.33%	Greece	3.66%	2.85%	Philippines	4.45%	2.13%
Austria	5.53%	3.77%	Hong Kong	11.58%	11.33%	Poland	10.13%	3.27%
Belgium	10.27%	2.33%	Hungary	20.68%	4.90%	Portugal	8.04%	3.27%
Brazil	2.65%	1.03%	Iceland	5.18%	3.73%	Russia	2.79%	1.87%
Brunei	3.65%	14.98%	India	7.50%	1.09%	Saudi Arabia	2.38%	5.25%
Bulgaria	13.35%	4.99%	Indonesia	2.10%	1.53%	Singapore	6.32%	1.72%
Cambodia	21.81%	5.98%	Ireland	6.48%	3.45%	Slovak	17.52%	5.96%
Canada	4.58%	2.87%	Israel	3.26%	2.88%	Slovenia	9.03%	5.80%
Chile	1.62%	4.20%	Italy	5.17%	2.16%	South Africa	4.96%	2.97%
China	16.96%	0.82%	Japan	1.56%	0.79%	Spain	5.08%	2.54%
Columbia	2.94%	2.18%	Korea	11.75%	1.58%	Sweden	5.28%	3.34%
Costa Rica	8.37%	4.82%	Latvia	7.56%	5.42%	Switzerland	3.57%	5.12%
Croatia	4.75%	2.92%	Lithuania	6.71%	4.08%	Taiwan	17.29%	3.13%
Cyprus	5.12%	5.42%	Luxembourg	13.71%	13.90%	Thailand	19.23%	2.52%
Czech	17.37%	3.63%	Malaysia	39.59%	3.64%	Tunisia	14.83%	4.56%
Denmark	2.76%	1.64%	Malta	3.43%	2.83%	Turkey	14.30%	2.31%
Estonia	11.34%	5.22%	Mexico	8.91%	3.21%	UK	3.40%	3.16%
Finland	7.32%	2.56%	Netherlands	4.33%	0.75%	USA	1.71%	1.28%
France	5.76%	2.59%	New Zealand	3.56%	2.79%	Viet Nam	36.42%	5.93%

Table 7: Breakdown of the Gains from Trade into those from Trade in Intermediate Goods and those from Final Goods as of 2011

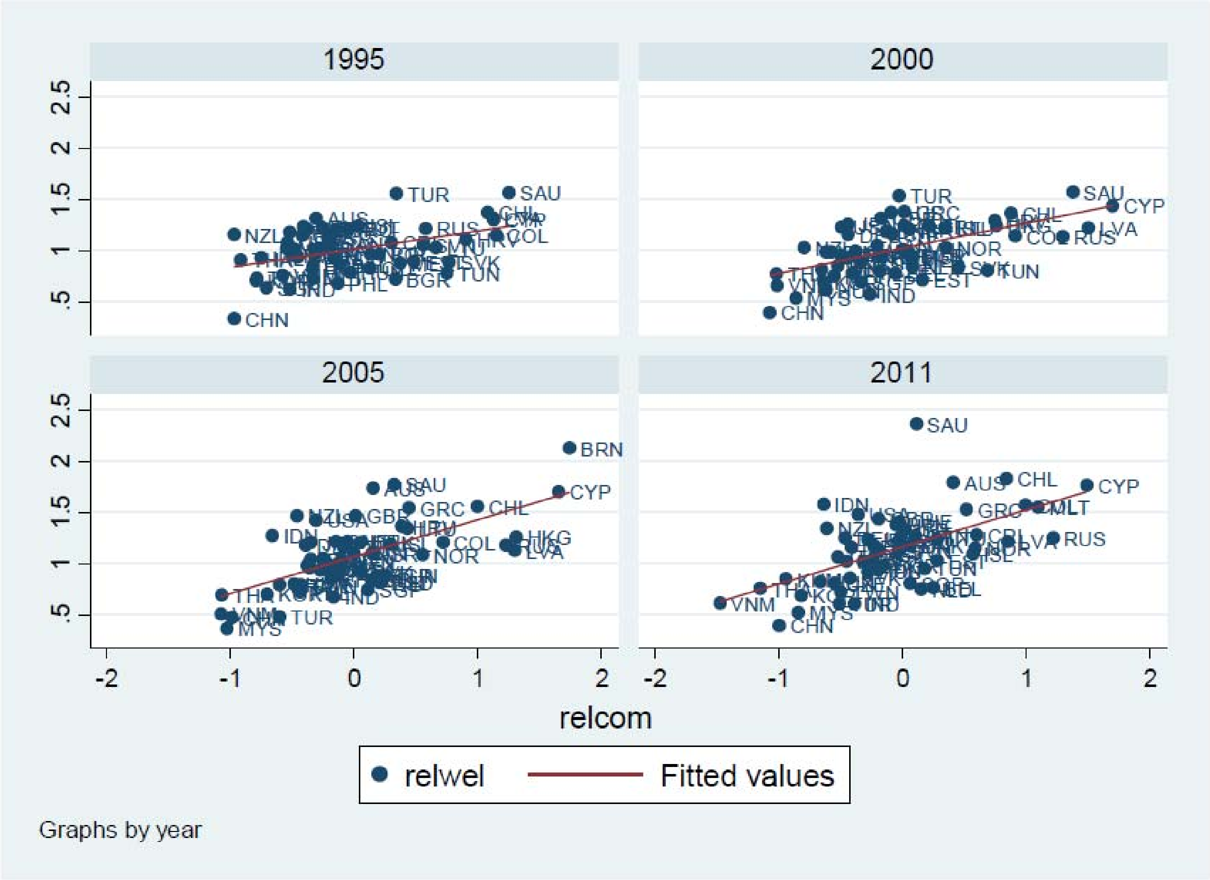

Figure 6: GFT_n^{TIG} / GFT_n^{LQ}: Gains from trade under TIG / Gains from trade in this paper (y-axis) vs. $\ln D_n - \ln \widetilde{D}_n$: ln (comp. in interm. goods/comp. in final goods) (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

goods. Moreover, not only did the developing countries gain a lot more from trade, they also gain significantly more from trade in intermediate goods than from trade in final goods.

4.2 Change in gains from trade

Next, we compute the change in gains from trade for each country n during a period by calculating the difference between the gains from trade in the beginning year and the ending year. The changes in gains from trade over each of the four periods 1995-2000, 2000-2005, 2005-2011 and 1995-2011 are given in Tables 9 and 10 in Appendix D.

From Table 9, we see that during 1995-2011, for the OECD countries, the average change in gains from trade in intermediate goods is 1.18% while the average change in gains from trade in final goods is 0.08%. This implies that, on average, for the OECD countries, the contribution of fragmentation (i.e. trade in intermediate goods) to the total gains from trade has increased during

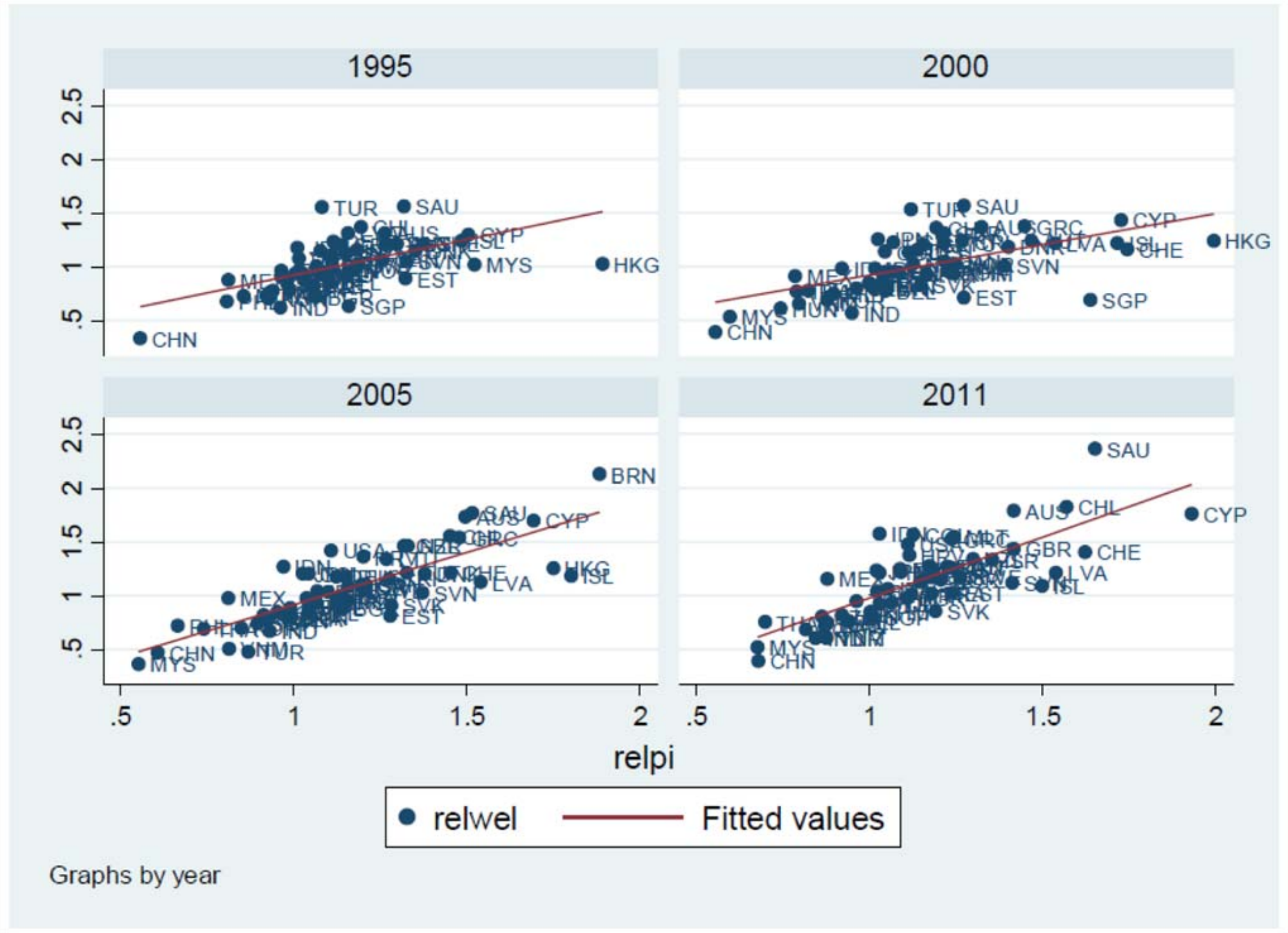

Figure 7: GFT_n^{TIG} / GFT_n^{LQ}: Gains from trade under TIG / Gains from trade in this paper (y-axis) vs. π_{nn} / $\widetilde{\pi}_{nn}$: home share in interm. goods / home share in final goods (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

1995-2011. More importantly, it can be seen that the change in gains from trade in intermediate goods are not proportional to the change in gains from trade in final goods. In some countries, they are of different signs. This distinction is what we would like to highlight in this paper so as to demonstrate that the TIG model over-simplifies the picture, as the TIG model would imply that the change in gains from trade in intermediate goods is proportional to that in final goods.

From Table 10, it can be seen that for the non-OECD countries the average change in gains from trade in intermediate goods is 2.99% while the average change in gains from trade in final goods is -0.09%. This again implies that for the non-OECD countries the contribution of fragmentation to the total gains from trade has increased during 1995-2011.

From Tables 9 and 10, we see that, during 1995-2011, the average increase in gains from intermediate goods trade for all countries in the sample, 2.32%, is distinctly higher than the average increase in gains from final goods trade, -0.03%. This suggests that gains from trade due to fragmentation is becoming more important over time for both developed and less developed countries. Figure 8 summarizes the results in Tables 9 and 10 diagrammatically. It plots the change in gains from trade in final goods during 1995-2011 (y-axis) against the change in gains from trade in intermediate goods during 1995-2011 (x-axis). <Figure 8 about here>

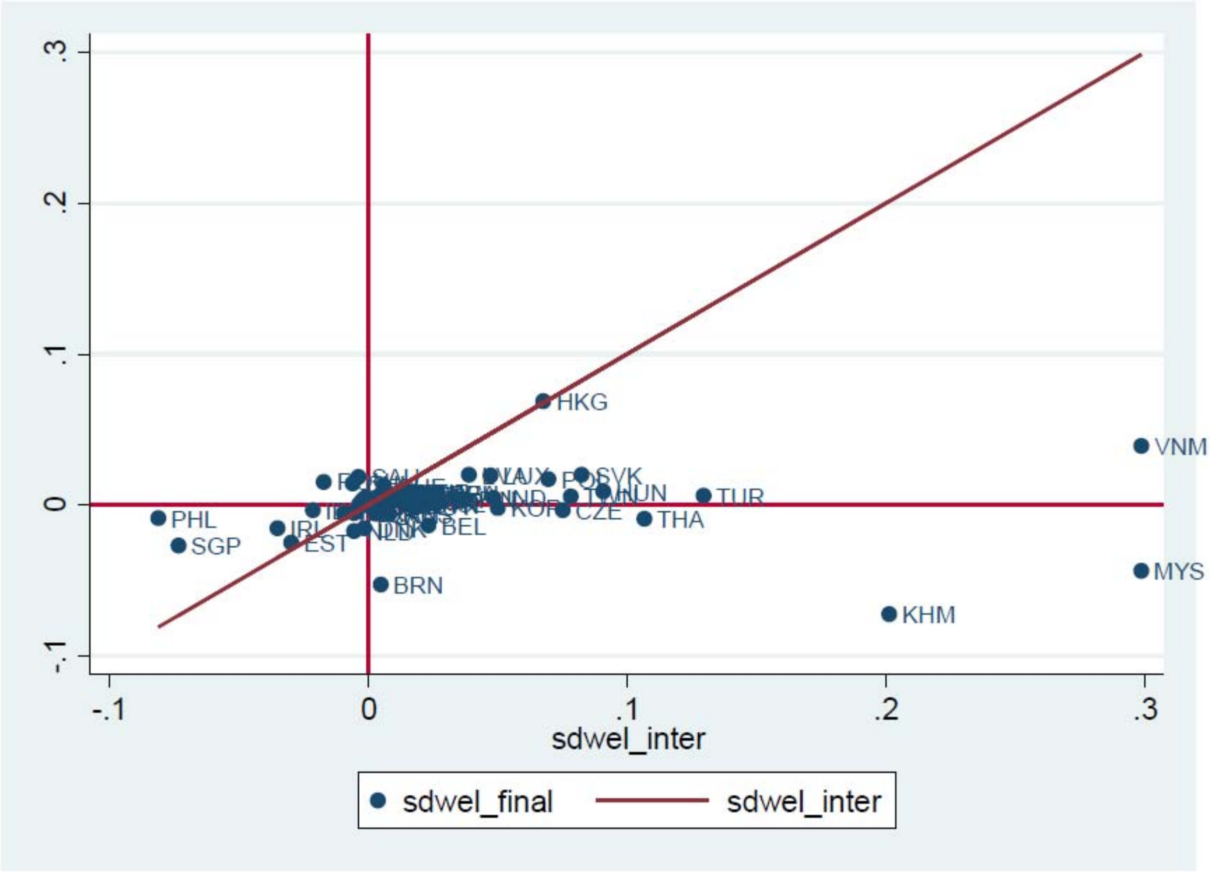

Figure 8: ΔGFT in Final Goods 1995-2011 (y-axis) vs. ΔGFT in Intermediate Goods 1995-2011 (x-axis)

5 Extension: Gains from Trade under a Multi-sector Model

So far, we have been using a one-sector model, though we make use of data of trade flows in intermediate goods and final goods separately in our empirical work. As Costinot and Rodriguez-Clare (2014) point out, the gains from trade calculated using a multi-sector model can be substantially different from that calculated using a one-sector model, as the parameters for different sectors can be quite different. Furthermore, in a multi-sector setting, final goods in one sector are produced using intermediate goods from other sectors, i.e. there are input-output linkages across sectors,which can also lead to a different estimated value of the gains from trade. Such kind of input-output linkages have been analyzed by, for example, Caliendo and Parro (2015). However, Caliendo and

Parro (2015) adopt a multi-sector version of the TIG model, and so they do not separately make use of the data of trade flows in intermediate goods and final goods in their empirical analysis. In their empirical work, trade flows in the two types of goods are lumped together. Here in this extension, we introduce input-output linkages across sectors and, in contrast to the TIG model, we separately make use of the data of trade flows in intermediate goods and final goods in our empirical analysis. We want to see whether our results concerning gains from trade are robust to switching from a one-sector analysis to a multi-sector analysis. Specifically, under the multi-sector setting, we would like to know whether and how the extent to which the gains from trade calculated based on our model deviates from the TIG model is related to the strength of comparative advantage in intermediate goods versus final goods. Furthermore, we would like to know if the average increase in gains from trade in intermediate goods is distinctly greater than those in final goods during the period 1995-2011.

5.1 The Model

This section states the main features of the model and the major results. For the detailed calculation, refer to Appendix F. There are K sectors, indexed by s. Sectors $s = 1, 2, ..., M$ are manufacturing sectors, $s = M + 1, M + 2, ..., K$ are service and primary (hereinafter referred to as S&P) sectors. Hereinafter, "goods" refers "goods and/or services". We define the utility function of the representative household in country n as

$$U_n = \exp\left\{ \sum_{s=1}^{K} \alpha_n^s \int_0^1 \ln\left[\widetilde{Q_n^s}\left(i\right)\right] di \right\} \quad \text{for } n = 1, 2, ..., N \tag{17}$$

where $\widetilde{Q}_n\left(i\right)$ is the quantity consumed of variety i of sector-s final good by the representative household in country n, and α_n^s is the expenditure share of sector-s final goods in country n. Thus, $\sum_{s=1}^{K} \alpha_n^s = 1$. We are only interested in gains from trade in final manufactured goods and trade in intermediate manufactured and S&P goods used to produce manufactured goods. Thus, we assume that final S&P goods as well as intermediate manufactured and S&P goods used to produce S&P goods are non-tradable.

A final good or an intermediate good is produced by conversion from an input bundle. $\widetilde{Z_l^s}\left(i\right)$ denotes the efficiency of country l in converting a sector-s input bundle into a sector-s final good of variety $i \in [0, 1]$, and $Z_l^s\left(j\right)$ denotes the efficiency for converting a sector-s input bundle into a sector-s intermediate good of variety $j \in [0, 1]$. The production function of a sector-s input bundle in country n is given by:

$$y_n^s = \left(M_n^s\right)^{1-\beta_n^s} \left(l_n^s\right)^{\beta_n^s}, \text{ where } 0 < \beta_n^s < 1 \quad \text{for } s = 1, 2, ..., K \tag{18}$$

where y_n^s is the quantity of sector-s input bundle produced in country n; M_n^s is the corresponding quantity of the sector-s composite intermediate good (which is defined in equation (19) below); l_n^s

is the corresponding labor input. The quantity of sector-s composite intermediate good produced by n is determined by the following production function:

$$M_n^s = \exp\left\{\sum_{r=1}^{K} \gamma_n^{sr} \int_0^1 \ln\left[Q_n^{sr}(j)\right] dj\right\} \quad \text{for } s = 1, 2, ..., K, \tag{19}$$

where $Q_n^{sr}(j)$ is the quantity of variety j of sector-r intermediate good used by country n in the production of the sector-s composite intermediate good, γ_n^{sr} is the cost share of intermediate goods from sector r used to produce the sector-s composite intermediate good in country n. Thus, $\sum_{r=1}^{K} \gamma_n^{sr} = 1$ for all s. The random variable $Z_l^s(j)$ follows the Fréchet distribution, with the cumulative density function given by

$$\Pr[Z_l^s(j) < z] = e^{-\left[T_l^s\right] z^{-\theta^s}} \quad \forall j \in [0,1] \ \text{ for } s = 1, 2, ..., K, \tag{20}$$

where T_l^s is country l's technology stock for producing sector-s intermediate goods and $1/\theta^s$ is positively related to the variance of the distribution of $Z_l^s(j)$ $\forall j \in [0,1]$.

We assume that $\widetilde{Z_l^s}(i)$ follows the Fréchet distribution, with the cumulative density function given by

$$\Pr[\widetilde{Z_l^s}(i) < z] = e^{-\left[\widetilde{T_l^s}\right] z^{-\widetilde{\theta^s}}} \quad \forall i \in [0,1] \ \text{ for } s = 1, 2, ..., K, \tag{21}$$

where $\widetilde{T_l^s}$ is country l's technology stock for producing sector-s final goods and $1/\widetilde{\theta^s}$ is positively related to the variance of the distribution of $\widetilde{Z^s}_l(i)$ $\forall i \in [0,1]$.

The variables c_l^s, p_{nl}^s, β_n^s, P_l^s, Φ_l^s, π_{nl}^s, X_{nl}^s, X_n and $\widetilde{c}_l^s$, $\widetilde{p}_{nl}^s$, $\widetilde{\beta}_n^s$, $\widetilde{P}_l^s$, $\widetilde{\Phi}_l^s$, $\widetilde{\pi}_{nl}^s$, $\widetilde{X}_{nl}^s$, $\widetilde{X}_n$ are all similarly defined as in the one-sector model except that they are specific to the sector s.

Gains from Trade

Taking the model to the data, as we are interested only in gains from trade in manufactured final goods and trade in intermediate manufactured and S&P inputs used to produce manufactured goods, the total gains from trade is given by

$$\begin{aligned} \widehat{W_n^A} - 1 &= \prod_{s=1}^{M} \left(\widetilde{\pi}_{nn}^s\right)^{-\frac{\alpha_n^s}{\widetilde{\theta}^s}} \prod_{s=1}^{M} \prod_{r=1}^{K} \left(\pi_{nn}^r\right)^{-\frac{\alpha_n^s \delta_n^{sr}}{\theta^r}} - 1 \\ &\approx \underbrace{\left[\prod_{s=1}^{M} \left(\widetilde{\pi}_{nn}^s\right)^{-\frac{\alpha_n^s}{\widetilde{\theta}^s}} - 1\right]}_{\substack{\text{gains from trade} \\ \text{in final goods}}} \cdot \underbrace{\left[\prod_{s=1}^{M} \prod_{r=1}^{K} \left(\pi_{nn}^r\right)^{-\frac{\alpha_n^s \delta_n^{sr}}{\theta^r}} - 1\right]}_{\substack{\text{gains from trade} \\ \text{in intermediate goods}}} \end{aligned} \tag{22}$$

where δ_n^{sr} is the row s column r element of the Leontief inverse matrix minus the identity matrix as described in Appendix F.

If we lump together the trade flows of intermediate goods and final goods in each sector, the home market share in sector s of country n is given by

$$\overline{\pi}_{nn}^s = \widetilde{\pi}_{nn}^s = \pi_{nn}^s = \frac{X_{nn}^s + \widetilde{X}_{nn}^s}{X_n^s + \widetilde{X}_n^s} \quad \text{for } s = 1, 2, ..., K.$$

Now, suppose we adopt a multi-sector TIG model as described in Coli endo and Parro (2015). Under such a model, the gains from trade (starting from autarky) for the multi-sector TIG model is given by

$$\widehat{W_n^A}\Big|_{TIG} - 1 = \textstyle\prod_{s=1}^{M} \prod_{r=1}^{K} \left(\overline{\pi}^r_{nn}\right)^{-\frac{\alpha^s_n(\delta^{sr}_n + 1^{sr})}{\overline{\theta}^r}} - 1 \tag{23}$$

where 1^{sr} is a indicator variable which is equal to 1 *iff* $s = r$ and 0 otherwise.

We also estimate the sectoral gravity equations for trade in intermediate goods (used to produce manufactured goods)

$$\ln\left(\frac{X^s_{nl}}{X^s_{nn}}\right) = \ln D^s_l - \ln D^s_n - \theta^s \ln \tau^s_{nl} \quad \text{for } s = 1, 2, ..., K,$$

and sectoral gravity equations for trade in final goods

$$\ln\left(\frac{\widetilde{X}^s_{nl}}{\widetilde{X}^s_{nn}}\right) = \ln \widetilde{D}^s_l - \ln \widetilde{D}^s_n - \widetilde{\theta}^s \ln \tau^s_{nl} \quad \text{for } s = 1, 2, ..., M,$$

with $\ln \tau^s_{nl} = d^s_k + b^s + l^s + Legal^s + CU^s + Col^s + m^s_n$, to obtain the sectoral competitiveness in intermediate goods (used to produce manufactured goods) $\ln D^s_l$ for $s = 1, 2, ..., K$ and sectoral competitiveness in final goods $\ln \widetilde{D}^s_l$ for $s = 1, 2, ..., M$. Like in the one-sector model, we assume that $\theta^s = \widetilde{\theta}^s = \overline{\theta}^s = 4.0$ for all s. The definitions of the variables that are not yet defined so far are the same as in the one-sector model.

The aggregate competitiveness in intermediate goods and final goods are defined in Appendix F. They are expenditure-weighted averages of the estimated values of $\{D^s_l\}$ and $\left\{\widetilde{D}^s_l\right\}$ respectively.

5.2 Empirical results

Our empirical findings are summarized by Figures 9 and 10.

1. Figure 9 plots the ratio of gains from trade under multi-sector TIG to the gains from trade under our multi-sector model against the ratio of the multi-sector aggregate competitiveness in intermediate goods to the multi-sector aggregate competitiveness in final goods. This diagram is to be compared with Figure 6 under the one-sector model. <Figure 9 about here>

2. Figure 10 plots the gains from trade under multi-sector TIG to gains from trade under our multi-sector model against the ratio of home share in intermediate goods to home share in final goods. This diagram is to be compared with Figure 7 under the one-sector model. <Figure 10 about here>

Recall that under the one-sector setting, the TIG model (which does not separately make use of data of trade flows in intermediate goods and final goods respectively) under-estimates the gains from trade of only those countries with sufficiently large $\widetilde{\pi}_{nn}/\pi_{nn}$ (e.g. when the ratio is greater

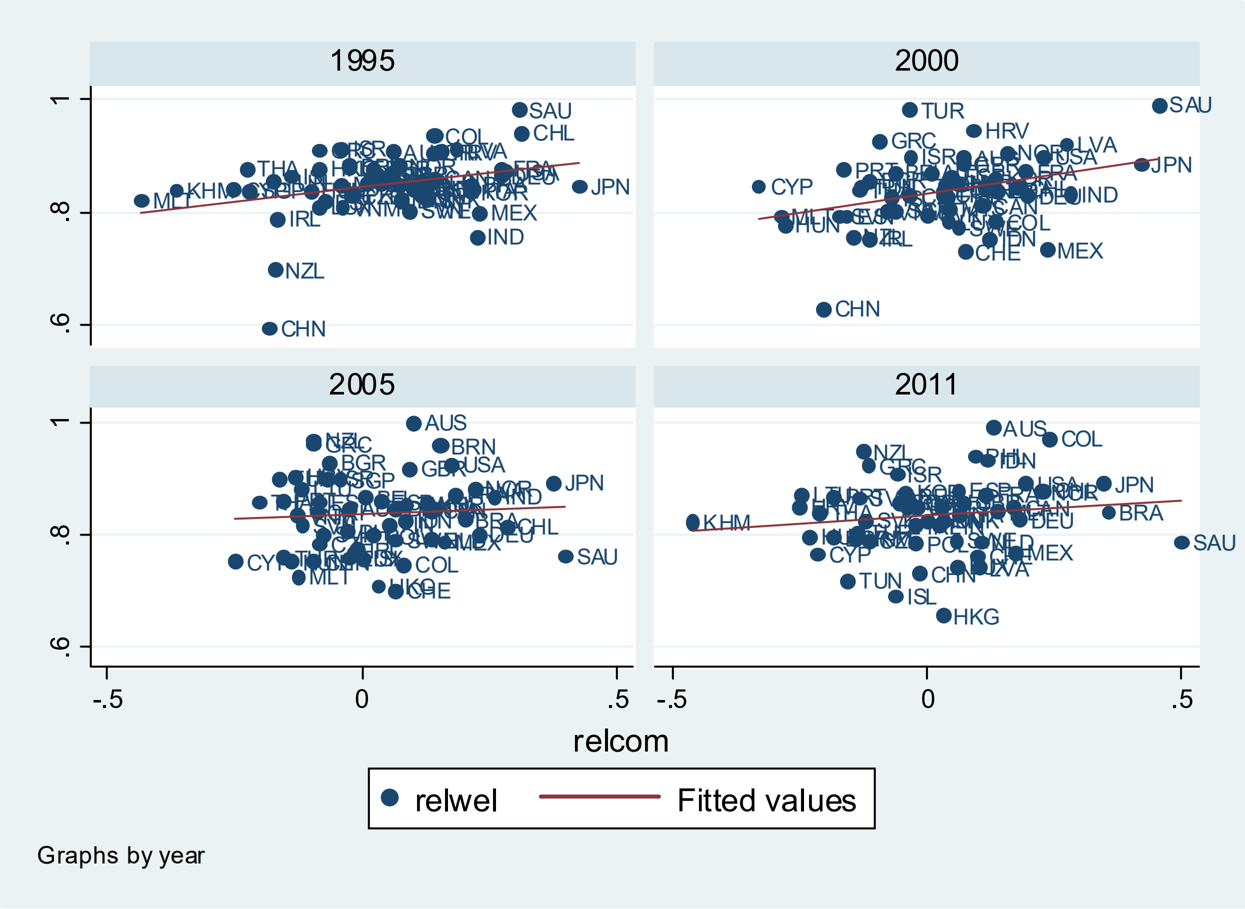

Figure 9: GFT_n^{TIG} / GFT_n^{LQ}: Gains from trade under multi-sector TIG / Gains from trade under the multi-sector model in this paper (y-axis) against $\ln D_n - \ln \widetilde{D}_n$: multi-sector aggregate competitiveness in intermediate goods / aggregate multi-sector competitiveness in final goods (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

than 1). It is interesting to note that, under the multi-sector setting, the TIG model under-estimates the gains from trade for almost all countries, as shown in Figure 10. The reason is that the gains from trade in intermediate service inputs are greatly under-estimated by the TIG model as all countries have home-bias in final services relative to intermediate services. This follows from the fact that the home-supplied market shares of final services are set to one for all countries as final services are assumed to be non-tradable. (This assumption is not too far from the fact.)[8] Just like in the one-sector model, for a country that has high ratio of home share in final service to home share in intermediate service, the TIG model can greatly under-estimate the gains from

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[8] For example, for the year 2011, in China, the domestic share in ''Post and telecommunications" as final goods is 0.994, in ''Real estate activities" is 0.995, in ''Computer and related activities" is 0.988, in ''R&D and other business activities" is 0.995, in ''Public admin. and social security" is 0.999, in ''Education" is 0.994, in ''Health and social work" is 0.997,

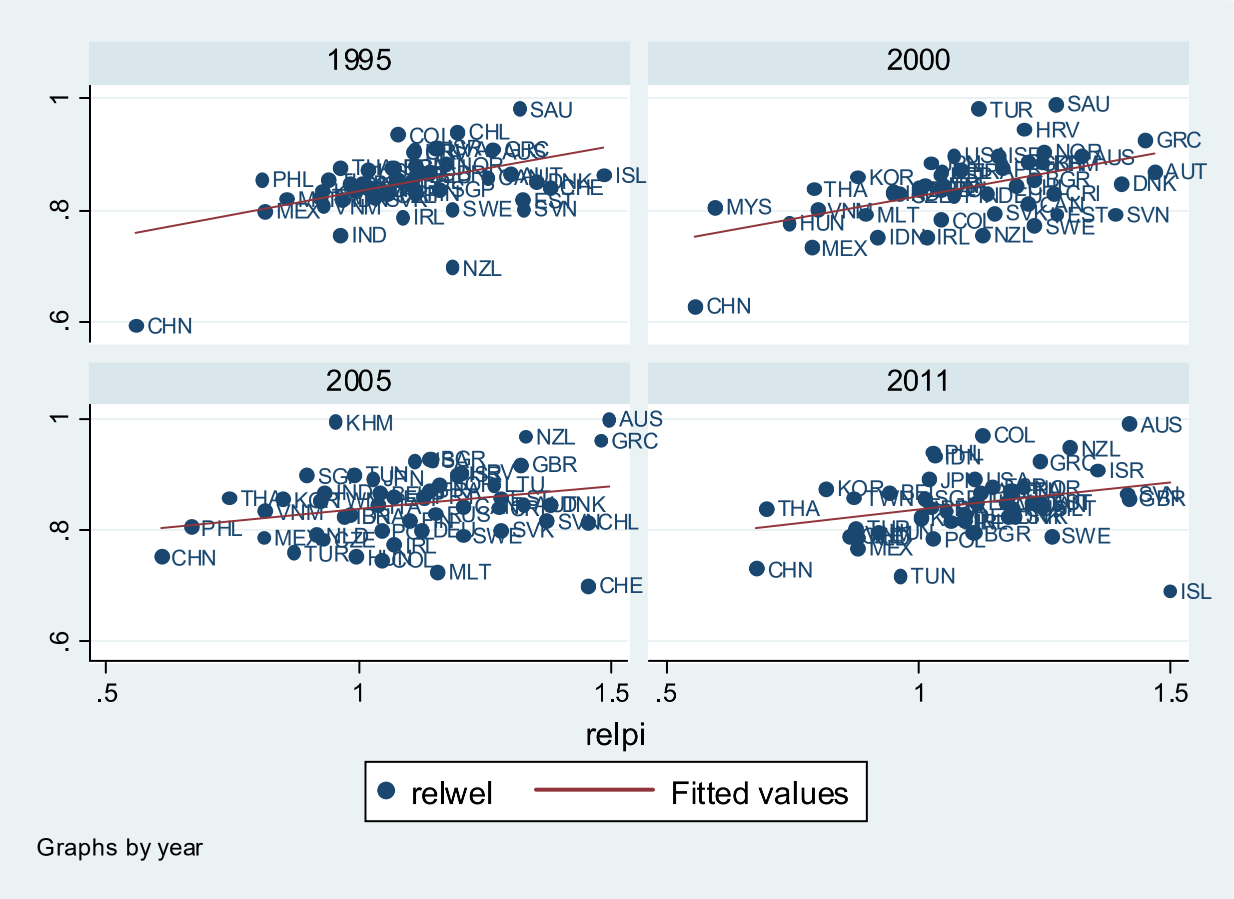
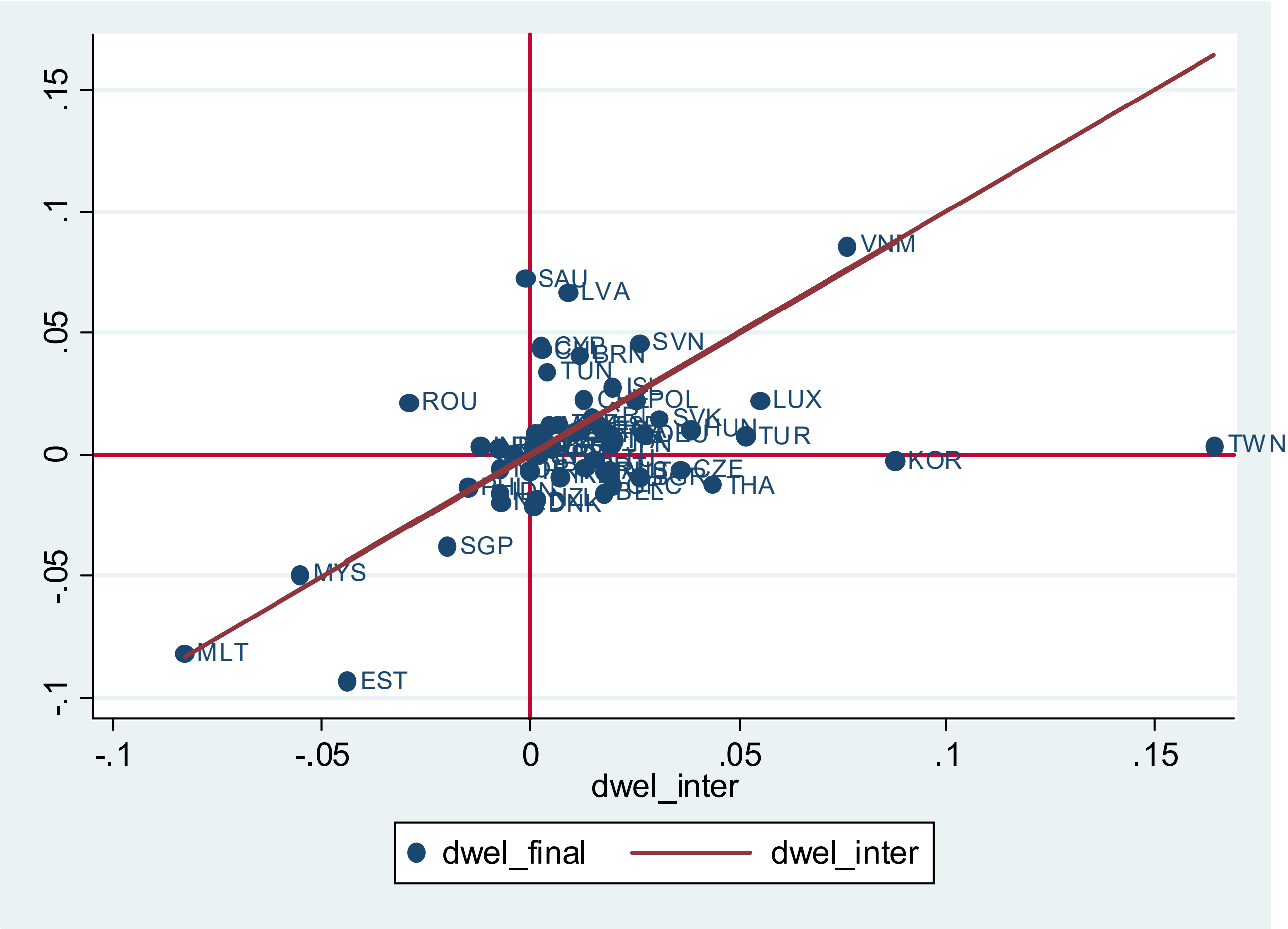


Figure 10: GFT_n^{TIG} / GFT_n^{LQ}: Gains from trade under multi-sector TIG / Gains from trade under the multi-sector model in this paper (y-axis) vs. $\pi_{nn}/\widetilde{\pi}_{nn}$: home share in intermediate goods / home share in final goods (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

intermediate service trade. The overall gains from trade is equal to the sum of the gains from trade in manufacturing goods and intermediate service and primary inputs. But the cost of intermediate primary goods only account for a small share of the total cost of intermediate service and primary goods on average. Thus, if the under-estimation of gains from trade in intermediate service inputs is sufficiently large in all countries, then the overall gains from trade is under-estimated by the TIG model for almost all countries, even those with small $\widetilde{\pi}_{nn}/\pi_{nn}$.

Nonetheless, the positive relationship between the relative gains from trade and comparative advantage depicted in Figures 6 and 7 continue to hold in the multi-sector setting. In other words, it is still true that the TIG model under-estimates the gains from trade to a larger extent for countries that have stronger comparative advantage in final goods versus intermediate goods. For example, in 2000, China's gains from trade are under-estimated by more than 30% by the TIG model (China is the country most under-estimated by the TIG model), and China is one of the countries with the strongest comparative advantage in final goods. On the other hand, the gains from trade for the US are almost not under-estimated by the TIG model at all, and the US is one of the countries with the strongest comparative advantage in intermediate goods.

We next examine the change in the gains from trade in intermediate goods (i.e. the change in the value of $\prod_{s=1}^{M}\prod_{r=1}^{K}(\pi_{nn}^{r})^{-\frac{\alpha_n^s\delta_n^{sr}}{\theta^r}} - 1$), and change in gains from trade in final goods (i.e. the change in the value of $\prod_{s=1}^{M}(\widetilde{\pi}_{nn}^{s})^{-\frac{\alpha_n^s}{\theta^s}} - 1$), from 1995 to 2011 for each country. Like in the one-sector model, countries gain distinctly more from intermediate goods trade than from final goods trade. The average increase in gains from intermediate goods trade for all countries in the sample is 1.18% and average increase in gains from final goods trade for all countries in the sample is 0.48%. To show how individual countries behave, we plot $\triangle$GFT in Final Goods 1995-2011 (y-axis) vs. $\triangle$GFT in Intermediate Goods 1995-2011 (x-axis) for the multi-sector model in the following diagram.



In sum, the most important results concerning gains from trade are robust to switching from a one-sector to a multi-sector analysis.

6 Conclusion and Remarks

The availability of inter-country input-output tables in recent years has enabled us to disaggregate bilateral total trade flows into bilateral trade flows in intermediate goods and final goods respectively. Separately making use of the data of bilateral trade flows in intermediate goods and final goods yields interesting results and insights. It enables us to estimate a country's competitiveness in intermediate goods and that in final goods separately and to estimate the strength of comparative advantage of a country in final goods versus intermediate goods. It also enables us to get a more accurate estimation of the gains from trade of a country and to link it to the country's strength of comparative advantage in final goods versus intermediate goods.

In this paper, we modify the Eaton-Kortum model and derive separate gravity equations for trade in intermediate goods and trade in final goods. Based on these equations and the data on actual bilateral trade flows in intermediate goods and final goods, we estimate countries' competitiveness in intermediate goods and in final goods. We then go on to calculate the gains from trade of countries based on an equation that separately accounts for both gains from trade in intermediate goods and that in final goods. We then compare our results with those obtained by using the tradeable intermediate goods model. We find that, across countries, the ratio of domestic market share in final goods to that in intermediate goods is positively correlated with the ratio of competitiveness in final goods to that in intermediate goods. We argue that when this ratio is higher, the country has stronger comparative advantage in final goods versus intermediate goods. The TIG model tends to underestimate the gains from trade more for countries with stronger comparative advantage in final goods, due to the fact that the gains from trade in intermediate goods contribute substantially more than the gains from trade in final goods to the overall gains from trade of a country.

We also find that, during 1995-2011, the average increase in gains from intermediate goods trade across all countries in our sample is distinctly higher than the average increase in gains from final goods trade. This suggests that gains from trade due to international fragmentation of production is becoming more important over time relative to gains from trade in final goods.

We find that the above results concerning gains from trade are robust to generalization to a multi-sector model with inter-sectoral input-output linkage. For future research, we can make use of this multi-sector model to explore other issues, such as how and why changes in foreign trade shares in intermediate goods over time differ across countries and across sectors.

References

[1] Anderson, James E. and Eric van Wincoop: Gravity with Gravitas: A Solution to the Border Puzzle, *American Economic Review*, **93**(1), 170-192 (2003)

[2] Antras, Pol and Alonso de Gortari: On the Geography of Global Value Chains, NBER working paper no. 23456 (2017)

[3] Arkolakis, Costas, Costinot, Arnaud and Andres Rodriguez-Clare: New Trade Models, Same Old Gains?, *American Economic Review*, **102**(1), 94–130 (2012)

[4] Baldwin, Richard E. and Daria Taglioni: Gravity Chains: Estimating Bilateral Trade Flows when Trade in Components and Parts Is Important, in Aaditya Mattoo, Zhi Wang and Shang-Jin Wei (eds.) *Trade in Value Added: Developing New Measures of Cross-Border Trade, Centre for Economic Policy and World Bank (2013)*

[5] Baldwin, Richard E., and Anthony Venables: Spiders and snakes: Offshoring and Agglomeration in the Global Economy, *Journal of International Economics* **90(2)**, 245–254 (2013)

[6] Chaney, Thomas: Distorted Gravity: The Intensive and Extensive Margins of International Trade, *American Economic Review,* **98**(4), 1707–1721 (2008)

[7] Caliendo, Lorenzo and Fernando Parro. 2015. "Estimates of the Trade and Welfare Effects of NAFTA." Review of Economic Studies.

[8] Costinot, Arnaud and Andres Rodriguez-Clare. 2014. "Trade Theory with Numbers: Quantifying the Consequences of Globalization." in Handbook of International Economics Volume 4, edited by G. Gopinath, E. Helpman, and K. Rogoff.

[9] Costinot, Arnaud; Jonathan Vogel, and Su Wang. 2013. "An Elementary Theory of Global Supply Chains." *Review of Economic Studies* **80**, 109–144 (2013)

[10] Eaton, J. and Kortum, S.: Technology, Geography and Trade, *Econometrica* **70**(5), 1741–1779 (2002)

[11] Eaton, J. and Kortum, S. 2012. "Putting Ricardo to Work." Journal of Economic Perspectives 26(2), Spring, 65-90.

[12] Grossman, Gene M., and Esteban Rossi-Hansberg: Trading Tasks: A Simple Theory of Offshoring, *American Economic Review* **98**(5): 1978-1997 (2008)

[13] Head, Keith and Thierry Mayer. 2014. "Gravity Equations: Workhorse, Toolkit, Cookbook." Handbook of International Economics Vol. 4, Elsevier Publisher, pp.131-195.

[14] Head, Keith, Thierry Mayer, and John Ries. 2010. "The erosion of colonial trade linkages after independence." Journal of International Economics.

[15] Hummels, D., Ishii, J., Yi, K., The nature and growth of vertical specialization in world trade, *Journal of International Economics* **54**, 75–96 (2001)

[16] Johnson, R.C. and G. Noguera: Accounting for intermediates: Production sharing and trade in value added, *Journal of International Economics* **86** 224–236 (2012)

[17] Kee, Hiau Looi and Heiwai Tang: "Domestic Value Added in Exports: Theory and Firm Evidence from China." American Economic Review, 106(6): 1402-36. (2016)

[18] Koopman, R., Zhi Wang, and Shang-Jin Wei: Tracing Value-added and Double Counting in Gross Exports, *American Economic Review* **104**(2): 459-494 (2014)

[19] Simonovska, Ina and Michael Waugh. 2014. "The Elasticity of Trade: Estimates and Evidence." Journal of International Economics, 92(1), 34-50.

A Data Description

To carry out our empirical work, we use data from various sources. Here is a summary of the data we use in the paper

- Bilateral value of trade of intermediate goods and final goods are obtained from the underlying inter-country input-output (ICIO) tables of the November 2015 version of Measuring Trade in Value Added (**TiVA**) data set, an OECD-WTO joint project to calculate the value added by a country in the production of any good or service that is exported to the destination country. This data set was first released in late May 2013, and was updated in June 2015 and November 2015. We only use the November 2015 version of the data set.
- The data for bilateral trade costs come from the GeoDist dataset of CEPII, which is also used by Head, Mayer and Ries (2010).
- We adopt all the above data without any modification, in order to avoid any possible bias caused by inappropriate treatment.
- In the underlying ICIO table of the TiVA dataset, we can directly observe the value of intermediate goods sourced from sector r of country l to be used in the production of goods in sector s of country n, X_{nl}^{sr}, as well as the value of sector-s final goods exported from country l to country n, $\widetilde{X}_{nl}^{s}$, together with the sectoral value-added of country n in sector s, V_n^s. The sectoral output for manufacturing sector s of country n, Y_n^s $(s = 1, ..., M)$, can be written as

  $$\begin{aligned} Y_n^s &= \textstyle\sum_{l=1}^{N} \sum_{r=1}^{K} X_{nl}^{sr} + V_n^s \text{ (total value of intermediate goods used plus value-added)} \\ &= \textstyle\sum_{m=1}^{N} \sum_{k=1}^{K} X_{mn}^{ks} + \sum_{m=1}^{N} \widetilde{X}_{mn}^{s} \text{ (total value of intermediate and final goods produced)} \end{aligned}$$

  In the one-sector model, we carry out the following aggregation. (Note that the source sectors of intermediate goods do not include primary sectors.)

  $$\begin{aligned} X_{nl} &= \textstyle\sum_{s=1}^{M} \sum_{r=1}^{K} X_{nl}^{sr}, \qquad X_n = \sum_{l=1}^{N} X_{nl} \\ \widetilde{X}_{nl} &= \textstyle\sum_{s=1}^{M} \widetilde{X}_{nl}^{s}, \qquad \widetilde{X}_n = \sum_{l=1}^{N} \widetilde{X}_{nl} \\ \text{with } \beta_n &= \frac{X_n}{\sum_{s=1}^{M} Y_n^s} \end{aligned}$$

  For the TIG model, $\overline{\pi}_{nn} = \frac{X_{nn}+\widetilde{X}_{nn}}{X_n+\widetilde{X}_n}$.

  In the multi-sector model, we carry out the following aggregation

  $$\begin{aligned} X_{nl}^{r} &= \textstyle\sum_{s=1}^{K} X_{nl}^{sr}, \qquad X_n^r = \sum_{l=1}^{N} X_{nl}^{s} \\ \text{with } \beta_n^s &= \frac{X_n^s}{Y_n^s} \end{aligned}$$

Countries in the Sample for Estimations

Argentina
Brazil
Canada
Costa Rica
Denmark
Germany
Iceland
Israel
Latvia
Malta
Norway
Russian Federation
Slovenia
Switzerland
Turkey
Australia
Brunei Darussalam
Chile
Croatia
Estonia
Greece
India
Italy
Lithuania
Mexico
Philippines
Saudi Arabia
South Africa
Taiwan
United Kingdom
Austria
Bulgaria
China
Cyprus
Finland
Hong Kong, China
Indonesia
Japan
Luxembourg
Netherlands
Poland
Singapore
Spain
Thailand
United States
Belgium
Cambodia
Columbia
Czech Republic
France
Hungary
Ireland
Korea
Malaysia
New Zealand
Portugal
Slovak Republic
Sweden
Tunisia
Viet Nam

Sector	Type	Sector	Type
Agriculture, hunting and fishing	Primary	Manufacturing nec; recycling	Manufacturing
Mining and quarrying	Primary	Electricity, gas and water supply	Service
Food products and beverages	Manufacturing	Construction	Service
Textiles products and footwear	Manufacturing	Wholesale and retail trade	Service
Products of wood and cork	Manufacturing	Hotels and restaurants	Service
Pulp, paper products and printing	Manufacturing	Transport and storage	Service
Coke, refined petroleum products	Manufacturing	Post and telecommunications	Service
Chemicals and chemical products	Manufacturing	Financial intermediation	Service
Rubber and plastics products	Manufacturing	Real estate activities	Service
Other mineral products	Manufacturing	Renting of machinery & equipment	Service
Basic metals	Manufacturing	Computer and related activities	Service
Fabricated metal products	Manufacturing	R&D and other business activities	Service
Machinery and equipment, nec	Manufacturing	Public admin. and social security	Service
Computer, Electronic equipment	Manufacturing	Education	Service
Electrical machinery and apparatus	Manufacturing	Health and social work	Service
Motor vehicles and trailers	Manufacturing	Other services	Service
Other transport equipment	Manufacturing	Private households employment	Service

B Variables used in the diagrams in this paper

Pi_nn: Country n's home-supplied market share in intermediate goods used in the production of manufactured goods

S_nn: Country n's home-supplied market share in manufactured final goods

Com_inter: ln (Competitiveness in exporting intermediate goods used in manufactured goods production) (relative to the mean)

Com_final: ln (Competitiveness in exporting manufactured final goods) (relative to the mean)

Com_EK: ln (Competitiveness in exporting manufactured goods under the TIG model) (relative to the mean)

wel_EK: Gains from trade relative to autarky under the TIG model

wel_LQ: Gains from trade relative to autarky under our model

sdwel_final: Cumulative change in gains from trade in manufactured final goods during 1995 – 2011

sdwel_inter: Cumulative change in gains from trade in intermediate goods used in the production of manufactured goods during 1995 – 2011

relpi: Pi_nn / S_nn

relcom_fnl: Com_final - Com_EK

T_final: ln(Technology stock in producing manufactured final goods) (relative to the mean)

T_interm: ln(Technology stock in producing intermediate goods used in the production of manufactured goods) (relative to the mean)

relT: T_interm - T_final

relcom: Com_inter - Com_final

relwel: wel_EK / wel_LQ

foreignaccess: Access to foreign intermediate goods

lw: ln (wage)

C Slopes and statistical significance

The slopes and statistical significance of the fitted lines in the figures are given below.

Figure	1995	2000	2005	2011
Figure 2	0.70*(0.38)	1.25***(0.25)	1.62***(0.20)	1.57*** (0.24)
Figure 3	1.04***(0.05)	1.05***(0.05)	1.04***(0.05)	1.01***(0.04)
Figure 4	0.63***(0.08)	0.61***(0.08)	0.65*** (0.09)	0.69***(0.10)
Figure 5	0.83** (0.34)	0.60*(0.33)	0.41 (0.34)	0.36 (0.38)
Figure 6	0.18***(0.05)	0.24***(0.05)	0.36***(0.06)	0.36***(0.07)
Figure 7	0.66***(0.13)	0.57***(0.10)	0.98***(0.10)	1.13***(0.13)
Figure 12	1.28***(0.06)	1.29***(0.06)	1.25***(0.06)	1.23***(0.06)
Figure 13	0.74***(0.07)	0.74***(0.08)	0.78***(0.09)	0.84***(0.09)
Figure 14	0.86*(0.43)	0.49 (0.41)	0.21 (0.42)	0.13 (0.46)
Figure 9	0.10**(0.04)	0.14***(0.05)	0.04 (0.06)	0.06 (0.05)
Figure 10	0.14***(0.05)	0.18***(0.05)	0.08* (0.04)	0.09**(0.05)

*** indicates 1% significance level, ** indicates 5% significance level, * indicates 10% significance level

Standard errors are in parentheses.

D Tables 8, 9 and 10

<Tables 8, 9, and 10 about here>

E Proof of Corollary 1

Step 1. First we want to prove that if $\widetilde{\pi}_{nn} > \pi_{nn}$ and $\beta_n < 0.333$ then $(\widetilde{\pi}_{nn})^{-1/\widetilde{\theta}} (\pi_{nn})^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} > (\overline{\pi}_{nn})^{-1/(\overline{\theta}\beta_n)}$.

Let a = expenditure on home-supplied final goods; b = total expenditure on final goods; c = expenditure on home-supplied intermediate goods; d = total expenditure on intermediate goods. Thus, $\widetilde{\pi}_{nn} = \frac{a}{b}$; $\pi_{nn} = \frac{c}{d}$ and $\overline{\pi}_{nn} = \frac{a+c}{b+d}$, where $0 < a < b$ and $0 < c < d$.

According to the data, for more than 78% of the observations, $\beta_n < 0.333$.[9] To be conservative, we assume that $\beta_n = 0.333$. We also assume that $\overline{\theta} = \theta = \widetilde{\theta} = 4.0$, following Simonovska and Waugh (2014). Thus,

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[9] 340 out of a total of 434 observations have $\beta_n < 0.333$.

Country	Gains from trade		Country	Gains from trade		Country	Gains from trade	
	Our Model	TIG		Our Model	TIG		Our Model	TIG
Argentina	4.85%	6.42%	Germany	7.51%	9.37%	Norway	6.97%	8.01%
Australia	4.33%	7.76%	Greece	6.62%	10.09%	Philippines	6.69%	8.11%
Austria	9.51%	11.95%	Hong Kong	24.23%	31.58%	Poland	13.73%	12.63%
Belgium	12.84%	9.82%	Hungary	26.59%	21.69%	Portugal	11.57%	11.71%
Brazil	3.70%	3.86%	Iceland	9.11%	9.94%	Russia	4.71%	5.87%
Brunei	19.18%	55.82%	India	8.67%	5.22%	Saudi Arabia	7.76%	18.35%
Bulgaria	19.01%	18.52%	Indonesia	3.67%	5.77%	Singapore	8.15%	6.57%
Cambodia	29.09%	24.67%	Ireland	10.16%	12.39%	Slovak	24.53%	20.91%
Canada	7.58%	9.61%	Israel	6.24%	8.30%	Slovenia	15.35%	17.22%
Chile	5.89%	10.77%	Italy	7.44%	7.89%	South Africa	8.07%	10.15%
China	17.92%	7.04%	Japan	2.37%	2.92%	Spain	7.75%	8.74%
Columbia	5.18%	8.14%	Korea	13.52%	9.22%	Sweden	8.80%	10.28%
Costa Rica	13.59%	17.39%	Latvia	13.39%	16.20%	Switzerland	8.87%	12.48%
Croatia	7.81%	10.73%	Lithuania	11.07%	13.73%	Taiwan	20.95%	15.09%
Cyprus	10.82%	19.09%	Luxembourg	29.52%	30.54%	Thailand	22.24%	16.71%
Czech	21.63%	17.38%	Malaysia	44.67%	23.32%	Tunisia	20.07%	18.99%
Denmark	4.44%	5.20%	Malta	6.35%	9.84%	Turkey	16.95%	10.29%
Estonia	17.15%	17.64%	Mexico	12.41%	14.33%	UK	6.67%	9.58%
Finland	10.07%	9.37%	Netherlands	5.12%	3.83%	USA	3.01%	4.44%
France	8.50%	8.67%	New Zealand	6.45%	8.64%	Viet Nam	44.50%	27.23%

Table 8: Gains from Trade as of 2011

Country	Intermediate Goods				Final Goods				Total
	95-00	00-05	05-11	95-11	95-00	00-05	05-11	95-11	95-11
Australia	-0.12%	-0.09%	0.53%	0.31%	0.03%	0.56%	-0.14%	0.45%	0.77%
Austria	-0.11%	0.81%	1.02%	1.72%	0.81%	-0.70%	-0.24%	-0.13%	1.65%
Belgium	0.09%	-0.78%	2.17%	2.37%	-0.56%	-0.31%	-0.49%	-1.36%	0.93%
Canada	1.41%	-0.59%	-0.53%	0.29%	0.47%	-0.65%	-0.38%	-0.57%	-0.29%
Denmark	-0.17%	0.33%	-0.33%	-0.16%	-0.04%	-0.23%	-1.27%	-1.54%	-1.75%
Finland	0.91%	0.37%	2.49%	3.76%	0.10%	0.24%	0.02%	0.37%	4.24%
France	1.59%	0.01%	1.05%	2.65%	0.56%	0.04%	0.21%	0.81%	3.55%
Germany	1.37%	0.17%	1.09%	2.63%	0.74%	-0.12%	0.16%	0.78%	3.50%
Greece	-0.01%	-0.20%	0.49%	0.28%	0.72%	0.02%	-0.71%	0.03%	0.32%
Ireland	-0.43%	-2.11%	-0.98%	-3.52%	-0.58%	-0.83%	-0.16%	-1.56%	-5.36%
Iceland	0.99%	0.86%	0.81%	2.66%	0.81%	-0.17%	-0.51%	0.13%	2.89%
Israel	-0.73%	1.42%	-0.94%	-0.25%	-0.22%	0.33%	0.18%	0.29%	0.05%
Italy	0.86%	0.16%	0.64%	1.66%	0.42%	-0.17%	0.21%	0.46%	2.17%
Japan	0.15%	0.39%	0.40%	0.94%	0.15%	0.13%	0.08%	0.37%	1.32%
Korea	1.66%	-0.53%	3.88%	5.01%	0.01%	-0.42%	0.23%	-0.18%	4.90%
Luxembourg	1.70%	1.14%	1.88%	4.72%	4.28%	-2.87%	0.53%	1.95%	7.50%
Netherlands	-0.40%	-1.16%	1.00%	-0.56%	-0.81%	-0.83%	-0.08%	-1.72%	-2.37%
New Zealand	-0.22%	-0.28%	0.87%	0.37%	-0.76%	1.24%	-0.32%	0.15%	0.54%
Norway	0.21%	-0.55%	-0.21%	-0.55%	0.37%	-0.66%	-0.24%	-0.52%	-1.12%
Portugal	-0.64%	0.10%	0.50%	-0.04%	0.48%	-0.35%	-0.09%	0.05%	0.01%
Spain	2.22%	-0.70%	-0.89%	0.63%	1.07%	-0.30%	0.08%	0.85%	1.54%
Sweden	1.42%	-0.18%	-0.01%	1.23%	0.75%	-0.39%	0.06%	0.42%	1.71%
Switzerland	1.04%	0.38%	-0.82%	0.59%	2.12%	-1.42%	-0.58%	1.28%	1.95%
UK	-0.07%	-0.49%	0.98%	0.42%	0.31%	-0.13%	0.44%	0.62%	1.08%
USA	0.10%	-0.11%	0.23%	0.22%	0.29%	0.09%	0.03%	0.41%	0.64%

Table 9: Change in Gains from Trade for OECD (i.e. Developed) Countries

Country	Intermediate Goods				Final Goods				Total
	95-00	00-05	05-11	95-11	95-00	00-05	05-11	95-11	95-11
Argentina	0.19%	1.61%	0.17%	1.97%	0.27%	0.49%	0.06%	0.82%	2.83%
Brazil	0.93%	0.23%	-0.06%	1.10%	0.22%	-0.13%	0.24%	0.32%	1.44%
Bulgaria	-4.09%	3.65%	0.32%	-0.11%	0.50%	-0.11%	0.08%	0.48%	0.42%
Chile	-0.10%	-0.36%	-0.16%	-0.62%	-0.37%	0.12%	0.61%	1.44%	0.82%
China	-0.79%	2.11%	-1.32%	0.00%	0.02%	0.30%	-0.40%	-0.07%	-0.08%
Croatia	-0.03%	0.19%	-0.62%	-0.46%	0.91%	-0.21%	-1.10%	-0.41%	-0.91%
Colombia	-0.15%	0.10%	0.47%	0.42%	-0.18%	-0.01%	0.75%	0.56%	1.00%
Cyprus	0.45%	-2.13%	0.74%	-0.94%	1.08%	-1.72%	0.12%	-0.52%	-1.54%
Czech	1.64%	3.77%	2.11%	7.52%	-0.32%	0.45%	-0.49%	-0.36%	7.39%
Estonia	9.07%	-5.35%	-6.71%	-2.99%	0.60%	-1.34%	-1.77%	-2.50%	-6.01%
Hungary	13.96%	-6.56%	1.67%	9.07%	0.36%	0.13%	-0.76%	0.90%	10.52%
Indonesia	0.37%	-2.03%	–0.48%	-2.15%	-0.15%	-0.31%	0.11%	-0.36%	-2.55%
India	-0.39%	1.99%	3.23%	4.83%	-0.21%	0.49%	0.16%	0.45%	5.34%
Lithuania	-0.72%	-0.41%	2.05%	0.93%	0.73%	-0.03%	0.00%	0.70%	1.71%
Latvia	1.31%	2.39%	0.18%	3.89%	4.28%	-2.87%	0.54%	1.95%	6.19%
Mexico	2.20%	-0.59%	-0.38%	1.23%	0.72%	-0.09%	0.28%	0.92%	2.26%
Malaysia	33.00%	26.53%	-29.66%	29.87%	-3.53%	-0.83%	-0.03%	-4.39%	26.13%
Philippines	-3.98%	5.17%	-9.31%	-8.13%	-1.00%	0.06%	0.06%	-0.88%	-9.29%
Poland	2.53%	1.95%	2.49%	6.97%	1.06%	0.33%	0.34%	1.74%	8.99%
Romania	-0.56%	0.37%	-1.52%	-1.71%	0.52%	0.50%	0.52%	1.54%	-0.16%
Russia	-0.14%	0.46%	0.50%	0.82%	-0.93%	0.22%	0.12%	-0.59%	0.24%
Slovakia	7.33%	-0.59%	1.51%	8.24%	2.87%	0.63%	-1.52%	1.98%	10.90%
Slovenia	2.35%	-1.16%	0.72%	1.91%	0.98%	-1.26%	0.24%	-0.04%	1.98%
Thailand	3.08%	4.28%	3.30%	10.66%	-1.06%	-0.01%	0.14%	-0.93%	9.91%
Turkey	0.56%	9.80%	2.58%	12.95%	0.48%	-0.60%	0.75%	0.63%	12.88%
Taiwan	0.94%	1.87%	5.00%	7.82%	1.14%	-0.62%	0.03%	0.55%	8.67%
Viet Nam	7.27%	17.70%	4.91%	29.88%	0.82%	1.74%	1.35%	3.90%	35.80%
South Africa	1.94%	0.68%	-0.97%	1.65%	-0.06%	0.25%	0.70%	0.89%	2.62%

Table 10: Change in Gains from Trade for non-OECD (i.e. Developing) Countries

$$\left(\frac{1}{\widetilde{\overline{\theta}}}\right) = 0.25 \text{ and } \frac{1-\beta_n}{\theta\beta_n} = 0.5 \text{ and } \frac{-1}{\overline{\theta}\beta_n} = -\left(\frac{1}{\widetilde{\overline{\theta}}}\right) - \left(\frac{1-\beta_n}{\theta\beta_n}\right) = -0.75.$$

Note that $\widetilde{\pi}_{nn} > \pi_{nn} \iff ad > bc$. Moreover, we assume that $2ab + bc - cd > 0$, which holds for more than 95% of the observations.[10] Thus, we have

$$\begin{aligned}
(ad-bc)\,(2ab+bc-cd) &> 0 \\
(ad-bc)\,[2\,(ab+bc)-(bc+cd)] &> 0 \\
2\left(\frac{ad-bc}{bc+cd}\right) &> \frac{ad-bc}{ab+bc} \\
1+2\left(\frac{ad-bc}{bc+cd}\right) &> 1+\frac{ad-bc}{ab+bc} = \frac{ab+ad}{ab+bc}, \text{ which is great than one, since } ad > bc, \\
\Longrightarrow \qquad \left(\frac{ad+cd}{bc+cd}\right)^2 &> \frac{ab+ad}{ab+bc} \\
\text{since } (1+x)^2 &> 1+2x \text{ where } x = \frac{ad-bc}{bc+cd} \text{ and } 1+x = \frac{ad+cd}{bc+cd} \\
\Leftrightarrow \qquad \left(\frac{a+c}{b+d}\cdot\frac{d}{c}\right)^2 &> \left(\frac{a}{b}\cdot\frac{b+d}{a+c}\right) \\
\Leftrightarrow \qquad \left(\frac{a+c}{b+d}\cdot\frac{d}{c}\right)^{\frac{1-\beta_n}{\theta\beta_n}} &> \left(\frac{a}{b}\cdot\frac{b+d}{a+c}\right)^{\frac{1}{\widetilde{\overline{\theta}}}} \\
\Leftrightarrow \qquad \left(\frac{a}{b}\right)^{-\frac{1}{\widetilde{\overline{\theta}}}}\left(\frac{c}{d}\right)^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} &> \left(\frac{a+c}{b+d}\right)^{-\frac{1}{\widetilde{\overline{\theta}}}-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} \\
\Leftrightarrow \qquad (\widetilde{\pi}_{nn})^{-1/\widetilde{\theta}}\,(\pi_{nn})^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)} &> (\overline{\pi}_{nn})^{-1/(\overline{\theta}\beta_n)}
\end{aligned}$$

Therefore, for at least 73% [which comes from 78% − (100% − 95%)] of the observations, $\widetilde{\pi}_{nn} > \pi_{nn}$ implies that the TIG model under-estimates the gains from trade. 73% is considered a very large fraction of the observations sufficient to deliver statistically significant correlation in the sample.

Step 2. Next, defining $R \equiv \left[(\widetilde{\pi}_{nn})^{-1/\widetilde{\theta}}\,(\pi_{nn})^{-\left(\frac{1-\beta_n}{\theta\beta_n}\right)}\right] / \left[(\overline{\pi}_{nn})^{-1/(\overline{\theta}\beta_n)}\right]$, we want to prove that an increase in $\widetilde{\pi}_{nn}/\pi_{nn}$ leads to an increase in R. That is, the curve of R on the y-axis against $\widetilde{\pi}_{nn}/\pi_{nn}$ on the x-axis has a positive slope.

$$\begin{aligned}
\ln R &= -0.25\ln\widetilde{\pi}_{nn} - 0.5\ln\pi_{nn} + 0.75\ln\overline{\pi}_{nn} \\
&= -0.25\ln\left(\frac{\widetilde{\pi}_{nn}}{\pi_{nn}}\right) - 0.75\ln\left(\frac{\pi_{nn}}{\overline{\pi}_{nn}}\right) \\
&= -0.25\ln\left(\frac{ad}{bc}\right) - 0.75\ln\left[\frac{c}{d}\left(\frac{b+d}{a+c}\right)\right]. \qquad (24)
\end{aligned}$$

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[10] 413 out of a total of 434 observations have $2ab + bc - cd > 0$.

Note that $ad > bc$ and $2ab + bc - cd > 0$ imply that

$$\begin{aligned} 2a^2bd + abcd &> bdc^2 \\ \Leftrightarrow \quad bd\,(2a - c)\,(a + c) &> 0 \\ \Leftrightarrow \quad 2a &> c \end{aligned}$$

First we examine the case when $\widetilde{\pi}_{nn} > \pi_{nn}$. From (24), we have

$$\frac{d \ln R}{da} = \frac{-0.25}{a} + \frac{0.75}{a + c} > 0 \qquad \text{since } 2a > c.$$

That is, given that $\widetilde{\pi}_{nn} > \pi_{nn}$, an increase in $\widetilde{\pi}_{nn}/\pi_{nn}$ (caused by an increase in a) leads to a rise in R. (Note that changes in a while keeping b unchanged would still capture all possible a/b ratios. Thus, it is enough to just consider changes in a.)

Second, we examine the case when $\widetilde{\pi}_{nn} < \pi_{nn}$. In that case, we have, $bc > ad$ and $2ab + bc > cd$. If we add the two inequalities, we have

$$\begin{aligned} 2ab + 2bc &> ad + cd \\ \Leftrightarrow \quad 2b\,(a + c) &> d\,(a + c) \\ \Leftrightarrow \quad 2b - d &> 0 \end{aligned}$$

From (24), we have

$$\frac{d \ln R}{db} = \frac{0.25}{b} - \frac{0.75}{b + d} < 0 \qquad \text{since } 2b > d.$$

That is, given that $\widetilde{\pi}_{nn} < \pi_{nn}$, an increase in $\widetilde{\pi}_{nn}/\pi_{nn}$ (caused by a decrease in b) leads to a rise in R as well. (Note that changes in b while keeping a unchanged would still capture all possible a/b ratios. Thus, it is enough to just consider changes in b.) ■

F Multi-sector extension: Detailed calculation

From (20), we can infer that the competitive price of variety j of sector-s intermediate goods (used to produce manufactured goods) exported from l to n is given by

$$p^s_{nl}(j) = \frac{c^s_l}{Z^s_l(j)} \tau^s_{nl} \quad \text{for } s = 1, 2, ..., K,$$

where

$$c^s_l = \left(\frac{\prod_{r=1}^{K} \left(P^r_l / \gamma^{sr}_l\right)^{\gamma^{sr}_l}}{1 - \beta^s_l} \right)^{1-\beta^s_l} \left(\frac{w_l}{\beta^s_l} \right)^{\beta^s_l} \quad \text{for } s = 1, 2, ..., K, \tag{25}$$

is the unit cost of an input bundle whose production function is given by equation (18) (with n set to l), with P_l^s being the unit price of the sector-s composite intermediate good, the production function of which is given by equation (19) (with n set to l). It can be easily shown that

$$P_n^s = (\Phi_n^s)^{-\frac{1}{\theta^s}} \quad \text{for } s = 1, 2, ..., K, \tag{26}$$

where

$$\Phi_n^s \equiv \textstyle\sum_{m=1}^{N} T_m^s \left(c_m^s \tau_{nm}^s\right)^{-\theta} \quad \text{for } s = 1, 2, ..., K,$$

which is defined as country n's global access to the sector-s intermediate goods.

The market share of the sector-s intermediate goods (used to produce manufactured goods) imported from country l in country n is therefore given by

$$\pi_{nl}^s = \frac{X_{nl}^s}{X_n^s} = \frac{T_l^s \left(c_l^s \tau_{nl}^s\right)^{-\theta^s}}{\Phi_n^s} = \frac{D_l^s \left(\tau_{nl}^s\right)^{-\theta^s}}{\Phi_n^s} \quad \text{for } s = 1, 2, ..., K, \tag{27}$$

where X_{nl}^s is the imports of sector-s intermediate goods from country l to country n, X_n^s is the total expenditure on sector-s intermediate goods in country n, and $D_l^s \equiv T_l^s \left(c_l^s\right)^{-\theta}$is country l's competitiveness in supplying sector-s intermediate goods.

From (21), we can infer that the competitive price of variety i of sector-s final goods that can potentially be exported from l to n is given by

$$\widetilde{p}_{nl}^s(i) = \frac{c_l^s}{\widetilde{Z_l^s}(i)} \tau_{nl}^s \quad \text{for } s = 1, 2, ..., M,$$

where c_l^s is given in (25). Note that $\widetilde{p}_{nl}^s(i) = \infty$ for $s = M+1, M+2, ..., K$ and $n \neq l$, as we assume that final S&P goods are non-tradable.

Similar to (27), the market share of sector-s final goods imported from country l in country n is given by

$$\widetilde{\pi}_{nl}^s = \frac{\widetilde{X}_{nl}^s}{\widetilde{X}_n^s} = \frac{\widetilde{T_l^s} \left(c_l^s \tau_{nl}^s\right)^{-\widetilde{\theta}^s}}{\widetilde{\Phi_n^s}} = \frac{\widetilde{D_l^s} \left(\tau_{nl}^s\right)^{-\widetilde{\theta}^s}}{\widetilde{\Phi_n^s}} \quad \text{for } s = 1, 2, ..., M,$$

where $\widetilde{X}_{nl}^s$ is the imports of sector-s final goods from country l to country n, $\widetilde{X}_n^s$ is the total expenditure on sector-s final goods in country n, $\widetilde{\Phi_n^s} \equiv \sum_{m=1}^{N} \widetilde{T_m^s} \left(c_m^s \tau_{nm}^s\right)^{-\widetilde{\theta}^s}$ is defined as country n's global access to sector-s final goods, and $\widetilde{D_l^s} \equiv \widetilde{T_l^s} \left(c_l^s\right)^{-\widetilde{\theta}^s}$ is the competitiveness of country l in supplying sector-s final goods. Note that $\widetilde{\pi}_{nl}^s = 0$ for $s = M+1, M+2, ..., K$ and $n \neq l$ as final S&P goods are non-tradable.

The exact price index of the sector-s composite final good captured by the subutility expression $\int_0^1 \ln \left[\widetilde{Q_n^s}(i)\right] di$ in the utility function (17) is given by

$$\widetilde{P_n^s} = \left(\widetilde{\Phi_n^s}\right)^{-1/\widetilde{\theta}^s} \quad \text{for } s = 1, 2, ..., K. \tag{28}$$

Gains from Trade

Welfare of country n, W_n, is defined as the real wage of n. The percentage change in real wage in country n is given by

$$\begin{aligned} d\ln W_n &= d\ln w_n - \sum_{s=1}^{K} \alpha_n^s d\ln \widetilde{P_n^s} \\ &= \textstyle\sum_{s=1}^K \alpha_n^s \left(d\ln w_n + \dfrac{1}{\widetilde{\theta}^s} d\ln \widetilde{\Phi_n^s} \right) \\ &= \textstyle\sum_{s=1}^K \alpha_n^s \left(d\ln w_n - d\ln c_n^s - \dfrac{d\ln \widetilde{\pi}_{nn}^s}{\widetilde{\theta}^s} \right) \end{aligned}$$

where the last equality follows from $\frac{d\ln \widetilde{\pi}_{nn}^s}{\widetilde{\theta}^s} = -d\ln c_n^s - \frac{1}{\widetilde{\theta}^s} d\ln \widetilde{\Phi_n^s}$.

According to (25) and (26), the percentage change in the unit cost of the input bundle is given by

$$\begin{aligned} d\ln c_n^s &= \beta_n^s d\ln w_n + (1-\beta_n^s) \textstyle\sum_{r=1}^K \gamma_n^{sr} d\ln P_n^r \qquad \text{for } s = 1, 2, ..., K, \\ &= \beta_n^s d\ln w_n - (1-\beta_n^s) \textstyle\sum_{r=1}^K \gamma_n^{sr} \dfrac{d\ln \Phi_n^r}{\theta^r}. \end{aligned}$$

$$\begin{aligned} \Rightarrow \quad d\ln w_n - d\ln c_n^s &= (1-\beta_n^s) \textstyle\sum_{r=1}^K \gamma_n^{sr} \left(d\ln w_n + \dfrac{d\ln \Phi_n^r}{\theta^r} \right) \qquad \text{for } s = 1, 2, ..., K, \\ &= (1-\beta_n^s) \textstyle\sum_{r=1}^K \gamma_n^{sr} \left[(d\ln w_n - d\ln c_n^r) - \dfrac{d\ln \pi_{nn}^r}{\theta^r} \right] \end{aligned} \tag{29}$$

where the last equality follows $d\ln \pi_{nn}^r = -\theta^r d\ln c_n^r - d\ln \Phi_n^r$.

For country n, define $\mathbf{c}_n \equiv \{\mathbf{d}\ln \mathbf{w_n} - \mathbf{d}\ln \mathbf{c_n^s}\}$, which is a $K*1$ vector, $\boldsymbol{\pi}_n \equiv \{-\frac{d\ln \pi_{nn}^s}{\theta^s}\}$, which is also a $K*1$ vector, $\mathbf{B}_n$ is defined as a diagonal matrix with the sth diagonal element being β_n^s, $\boldsymbol{\Gamma}_n \equiv \{\gamma_n^{sr}\}$ is the $K*K$ input-output matrix of country n. Thus, (29) can be rewritten as

$$\begin{aligned} \mathbf{c}_n &= (\mathbf{I} - \mathbf{B}_n) \boldsymbol{\Gamma}_n (\mathbf{c}_n + \boldsymbol{\pi}_n) \\ \Rightarrow \quad \mathbf{c}_n &= [\mathbf{I} - (\mathbf{I} - \mathbf{B}_n) \boldsymbol{\Gamma}_n]^{-1} (\mathbf{I} - \mathbf{B}_n) \boldsymbol{\Gamma}_n \boldsymbol{\pi}_n \\ &= \{[\mathbf{I} - (\mathbf{I} - \mathbf{B}_n) \boldsymbol{\Gamma}_n]^{-1} - \mathbf{I}\} \boldsymbol{\pi}_n \end{aligned}$$

where $[\mathbf{I} - (\mathbf{I} - \mathbf{B}_n) \boldsymbol{\Gamma}_n]^{-1}$ is a typical Leontief inverse matrix. Define δ_n^{sr} as the row s column r element of $[\mathbf{I} - (\mathbf{I} - \mathbf{B}_n) \boldsymbol{\Gamma}_n]^{-1} - \mathbf{I}$, then

$$\begin{aligned} d\ln W_n &= -\textstyle\sum_{s=1}^K \alpha_n^s \left(\dfrac{d\ln \widetilde{\pi}_{nn}^s}{\widetilde{\theta}^s} + \textstyle\sum_{r=1}^K \delta_n^{sr} \dfrac{d\ln \pi_{nn}^r}{\theta^r} \right) \\ &= -\textstyle\sum_{s=1}^K \alpha_n^s \dfrac{d\ln \widetilde{\pi}_{nn}^s}{\widetilde{\theta}^s} - \textstyle\sum_{s=1}^K \sum_{r=1}^K \alpha_n^s \delta_n^{sr} \dfrac{d\ln \pi_{nn}^r}{\theta^r} \end{aligned}$$

Thus the gains from trade (starting from autarky) of country n is given by

$$\widehat{W_n^A} - 1 = \textstyle\prod_{s=1}^K (\widetilde{\pi}_{nn}^s)^{-\frac{\alpha_n^s}{\widetilde{\theta}^s}} \prod_{s=1}^K \prod_{r=1}^K (\pi_{nn}^r)^{-\frac{\alpha_n^s \delta_n^{sr}}{\theta^r}} - 1 \tag{30}$$

In the special case of $\mathbf{\Gamma}_n = \mathbf{I}$ (no inter-sectoral input-output linkage), we have $\mathbf{I} - (\mathbf{I} - \mathbf{B}_n)\,\mathbf{\Gamma}_n = \mathbf{B}_n$, $\delta_n^{ss} = (1-\beta_n^s)/\beta_n^s$ and $\delta_n^{sr} = 0$ for $s \neq r$. The gains from trade will be reduced to

$$\widehat{W_n^A} - 1 = \textstyle\prod_{s=1}^{K} \left[\left(\widetilde{\pi}_{nn}^s\right)^{-\frac{1}{\theta^s}} \left(\pi_{nn}^s\right)^{-\frac{1-\beta_n^s}{\theta^s \beta_n^s}} \right]^{\alpha_n^s} - 1.$$

In this case, the overall change in welfare $\widehat{W_n^A}$ is the weighted geometric mean of the sectoral welfare change $\left(\widetilde{\pi}_{nn}^s\right)^{-\frac{1}{\theta^s}} \left(\pi_{nn}^s\right)^{-\frac{1-\beta_n^s}{\theta^s \beta_n^s}}$ for all s, with welfare change in each sector being equal to that in the one-sector case.

Taking the model to the data, as we are interested only in gains from trade in manufactured final goods and trade in intermediate manufactured and S&P goods used to produce manufactured goods, the total gains from trade is given by (22), and we compare it to the total gains from trade of the multi-sector TIG model given by (23).

We also define the aggregate competitiveness of country n in final goods as

$$\log \widetilde{D}_n = \textstyle\sum_{s=1}^{M} \alpha_n^s \ln \widetilde{D}_n^s$$

and the aggregate competitiveness of country n in intermediate goods as

$$\log D_n = \frac{\sum_{s=1}^{M} \sum_{r=1}^{K} \alpha_n^s \left(1-\beta_n^s\right) \gamma_n^{sr} \ln D_n^r}{\sum_{s=1}^{M} \alpha_n^s \left(1-\beta_n^s\right)}$$

both of which are the expenditure share weighted average of the levels of sectoral competitiveness.

G Online Appendix

G.1 An Alternative Model

In this appendix, we put forward a model which assumes that final and intermediate goods are differentiated according to the country of origin. We use this model to illustrate that the gravity equations that we derive can arise from many different settings. Thus, the gravity equations we obtain in the main body of the paper can arise from a rather general model.

The Setting. There are N countries in the world, indexed by $n = 1, ..., N$. Country n has labor endowment L_n, which serves as the only primary input in production of all kinds of goods. However, we can interpret labor metaphorically as a composite factor input that includes labor, capital, and land. Labor is fully mobile across sectors within the same country, but not mobile across countries. Labor wage in country n is denoted by w_n. The production of an intermediate or final good requires the conversion from a composite input called an input bundle, which is a combination of labor and the entire set of intermediate goods (which is called an composite intermediate good). We assume that all countries have the capability to produce a variety of intermediate good and a variety of final good. All goods are tradeable but there are trade costs.

A typical country imports intermediate goods from all over the world, then combine the entire set of intermediate goods with domestic labor to form input bundles, and then produces either intermediate goods or final goods from the input bundles. The goods are then exported to destinations all over the world. In equilibrium, all countries export some intermediate goods and some final goods to all other countries and to themselves. Markets for both intermediate and final goods are assumed to be perfectly competitive.

Preferences. In each country a representative household maximizes utility by choosing a consumption bundle of final goods, subject to the budget constraint. The utility function of the representative household in any country is given by

$$U = \left[\sum_{m=1}^{N} \left(\widetilde{q}_m\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad , \tag{31}$$

where $\widetilde{q}_m$ is the consumption of the final good produced by country m, and $\sigma > 1$ is the elasticity of substitution between each pair of final goods. The utility function of the representative consumer is the same for all countries.

Technology. Each final good or intermediate good is converted from the input bundle. Denote the efficiency of country l in converting the input bundle into a final good by $\widetilde{T}_l$, and denote the efficiency for converting the input bundle into an intermediate good by T_l. The production function of an input bundle in country n is given by:

$$y_n = \left(M_n\right)^{1-\beta_n} \left(l_n\right)^{\beta_n}, \text{ where } 0 < \beta_n < 1, \tag{32}$$

where y_n is the quantity of input bundle produced in country n; M_n is the corresponding quantity of the composite intermediate good (which is defined in equation (33) below); l_n is the corresponding labor input.

The quantity of composite intermediate good produced by n is determined by the following function:

$$M_n = \left[\sum_{m=1}^{N} \left(q_m\right)^{\frac{\sigma'-1}{\sigma'}} \right]^{\frac{\sigma'}{\sigma'-1}} \quad \forall n, \tag{33}$$

where q_m is the use of the intermediate good produced by country m, and $\sigma' > 1$ is the elasticity of substitution between each pair of intermediate goods.

The competitive price of final good exported from l to n is given by

$$\widetilde{p}_{nl} = \frac{c_l}{\widetilde{T}_l} \tau_{nl},$$

where

$$c_l = \left(\frac{P_l}{1-\beta_l}\right)^{1-\beta_l} \left(\frac{w_l}{\beta_l}\right)^{\beta_l}$$

is the unit cost of an input bundle corresponding to the production function (32), with P_l being the unit price of the composite intermediate good, the production function of which is given by equation (33).

The competitive price of intermediate good exported from l to n is given by

$$p_{nl} = \frac{c_l}{T_l}\tau_{nl}.$$

Gravity equation for final goods trade. With the utility function (31), we can derive a gravity equation for trade in final goods:

$$\widetilde{X}_{mn} = \frac{\widetilde{D}_n \widetilde{X}_m}{\widetilde{\Phi}_m} \left(\tau_{mn}\right)^{1-\sigma}$$

where $\widetilde{X}_{mn}$ is the exports of country n final good to country m, $\widetilde{D}_n$ is the competitiveness of country n in exporting its final good, $\widetilde{X}_m$ is the total expenditure on final goods in country m, $\widetilde{\Phi}_m = \sum_{l=1}^{N} \widetilde{D}_l \left(\tau_{ml}\right)^{1-\sigma}$ is the global access of final goods by country m, and $1-\sigma$ is the elasticity of trade in final goods. In fact, the same gravity equation can be obtained under many other models, such as different types of utility functions. The parameter corresponding to the elasticity of trade in final goods can vary across different model settings.

We assume that $\widetilde{D}_n = \widetilde{T}_n \left(c_n\right)^{1-\sigma}$, where c_n is the unit cost of an input bundle in country n, and $\widetilde{T}_n$ here stands for the technology level of country n in producing final good. The parameter corresponding to this technology term can vary across different model settings.

Thus, the market share of final good is given by

$$\widetilde{\pi}_{mn} = \frac{\widetilde{D}_n \left(\tau_{mn}\right)^{1-\sigma}}{\widetilde{\Phi}_m}$$

which is the similar to (7) in the main text. From this, we can derive a similar gravity equation as (13).

Gravity equation for intermediate goods trade. With the production function for the composite intermediate good (33), we can derive a gravity equation for trade in intermediate goods:

$$X_{mn} = \frac{D_n X_m}{\Phi_m} \left(\tau_{mn}\right)^{1-\sigma'}$$

where X_{mn} is the exports of country n intermediate good to country m, D_n is the competitiveness of country n in exporting its intermediate good, X_m is the total expenditure on intermediate goods in country m, $\Phi_m = \sum_{l=1}^{N} D_l \left(\tau_{ml}\right)^{1-\sigma'}$ is the global access of intermediate goods by country m, and $1-\sigma'$ is the elasticity of trade in intermediate goods. Again, the same gravity equation can be obtained under many other models. The parameter corresponding to the elasticity of trade in intermediate goods can vary across different model settings.

We assume $D_n = T_n (c_n)^{1-\sigma'}$, where c_n is the unit cost of an input bundle in country n, and T_n here stands for the technology level of country n in producing intermediate good. The parameter corresponding to this technology term can vary across different model settings.

Thus, the market share of intermediate good is given by

$$\pi_{mn} = \frac{D_n (\tau_{mn})^{1-\sigma'}}{\Phi_m}$$

which is the similar to (6) in the main text. From this, we can derive a similar gravity equation as (10).

G.2 Use of continuous distance for the gravity model

Comparing Tables 11 and 12, we see that the magnitude of the distance elasticity of trade in intermediate goods is smaller than that of trade in final goods.

<Tables 11 and 12 are about here>

Variable	1995	2000	2005	2008	2009	2010	2011
ln(Dist)	-0.90***	-0.82***	-0.82***	-0.80***	-0.81***	-0.81***	-0.81***
	(0.015)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Shared Border	0.45***	0.48***	0.46***	0.43***	0.42***	0.42***	0.38***
	(0.065)	(0.061)	(0.062)	(0.059)	(0.061)	(0.061)	(0.060)
Shared Language	0.18***	0.22***	0.22***	0.19***	0.17***	0.19***	0.18***
	(0.050)	(0.047)	(0.048)	(0.046)	(0.047)	(0.047)	(0.047)
Shared Legal	0.31***	0.25***	0.20***	0.21***	0.22***	0.19***	0.18***
	(0.028)	(0.027)	(0.027)	(0.026)	(0.027)	(0.027)	(0.027)
Shared Currency	-0.86***	-0.36***	-0.34***	-0.33***	-0.32***	-0.34***	-0.35***
	(0.15)	(0.068)	(0.065)	(0.063)	(0.064)	(0.064)	(0.063)
Colonial Linkage	0.44***	0.35***	0.34***	0.30***	0.33***	0.33***	0.35***
	(0.071)	(0.069)	(0.070)	(0.067)	(0.069)	(0.069)	(0.068)
Dest. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,595	3,600	3,600	3,600	3,600	3,600	3,600

*** indicates 1% significance level, ** indicates 5% significance level,

*** indicates 1% significance level

Table 11: Gravity Equation for Trade in Intermediate Goods and Services

Variable	1995	2000	2005	2008	2009	2010	2011
ln(Dist)	-1.16***	-0.96***	-0.92***	-0.91***	-0.92***	-0.92***	-0.90***
	(0.030)	(0.018)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Shared Border	0.44***	0.67***	0.64***	0.64***	0.63***	0.64***	0.63***
	(0.13)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Shared Language	0.24**	0.42***	0.49***	0.41***	0.40***	0.45***	0.39***
	(0.096)	(0.084)	(0.081)	(0.078)	(0.078)	(0.079)	(0.078)
Shared Legal	0.45***	0.33***	0.27***	0.28***	0.33***	0.34***	0.31***
	(0.055)	(0.048)	(0.046)	(0.045)	(0.045)	(0.045)	(0.044)
Shared Currency	-2.98***	-0.91***	-0.60***	-0.65***	-0.62***	-0.73***	-0.57***
	(0.29)	(0.12)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Colonial Linkage	0.52***	0.39***	0.40***	0.36***	0.30***	0.31***	0.34***
	(0.14)	(0.12)	(0.12)	(0.11)	(0.11)	(0.12)	(0.11)
Dest. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,561	3,579	3,582	3,590	3,587	3,589	3,585

*** indicates 1% significance level, ** indicates 5% significance level,

* indicates 10% significance level

Table 12: Gravity Equation for Trade in Manufactured Final Goods

G.3 Plotting $\widetilde{\Phi}_n$ against Φ_n

The strong correlation between $\widetilde{\Phi}_n$ (global access to final goods) and Φ_n (global access to intermediate goods) is shown in Figure 11. <Figure 11 about here>

G.4 Unpacking the determinants of China's final goods competitiveness

Figures 12, 13 and 14 show that China's rapid rise in competitiveness in final goods is mainly due to its rise in access to foreign intermediate goods and its low wage, but not due to its technology, which is quite low relative to the mean. <Figures 12, 13 and 14 are about here>

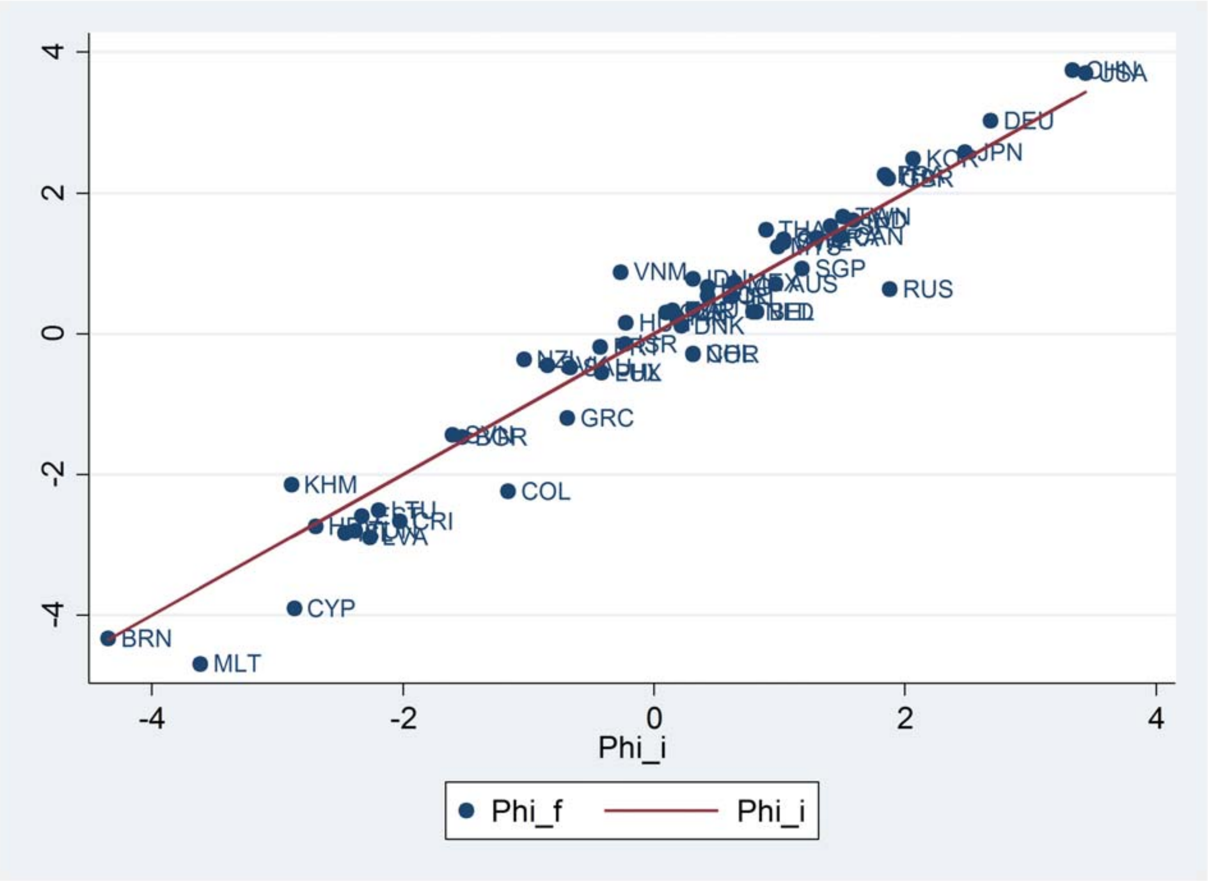

Figure 11: $\widetilde{\Phi}_n$: Global access to final goods (y-axis) vs. Φ_n: Global access to intermediate goods (x-axis)

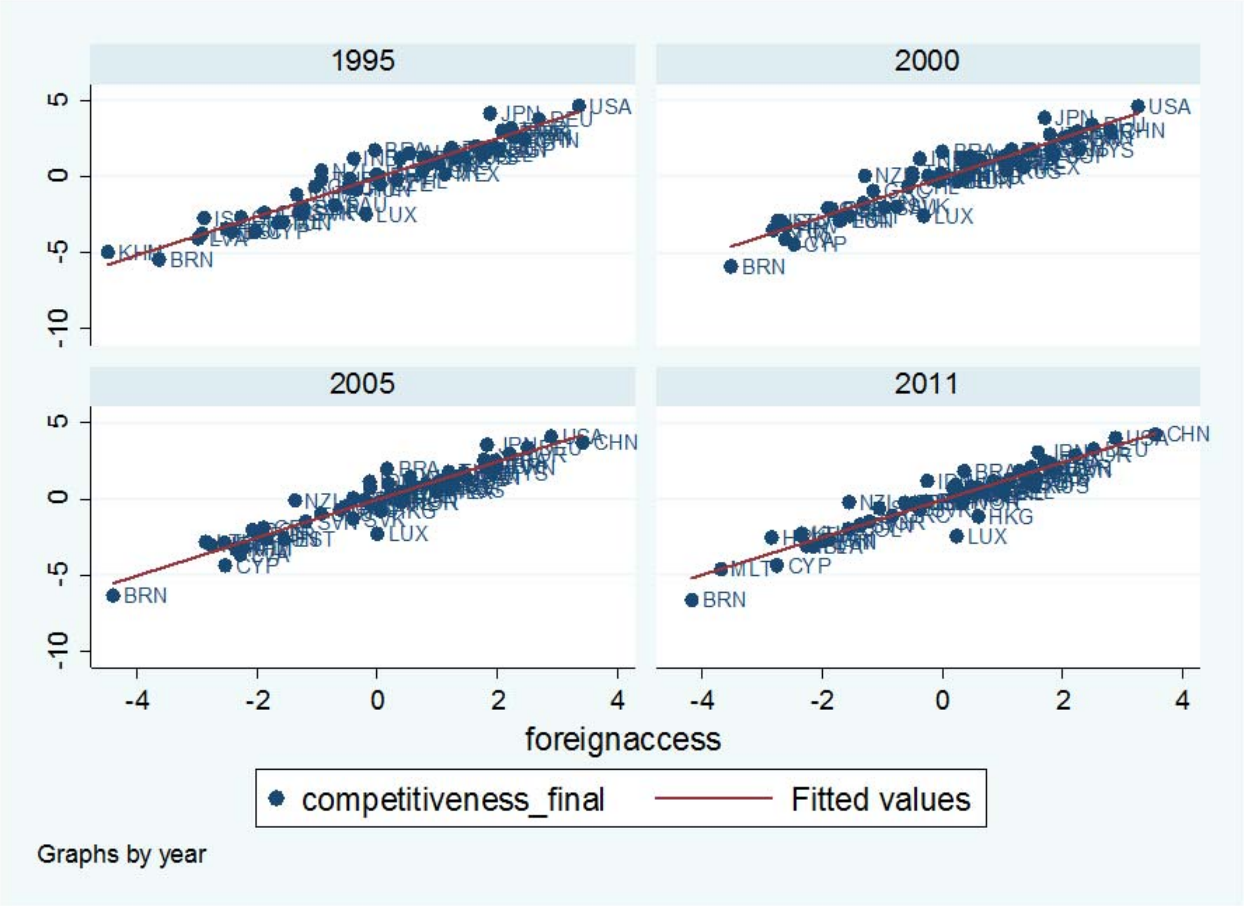

Figure 12: $\widetilde{D}_n$ (y-axis) vs. F_n: access to foreign intermediate goods (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

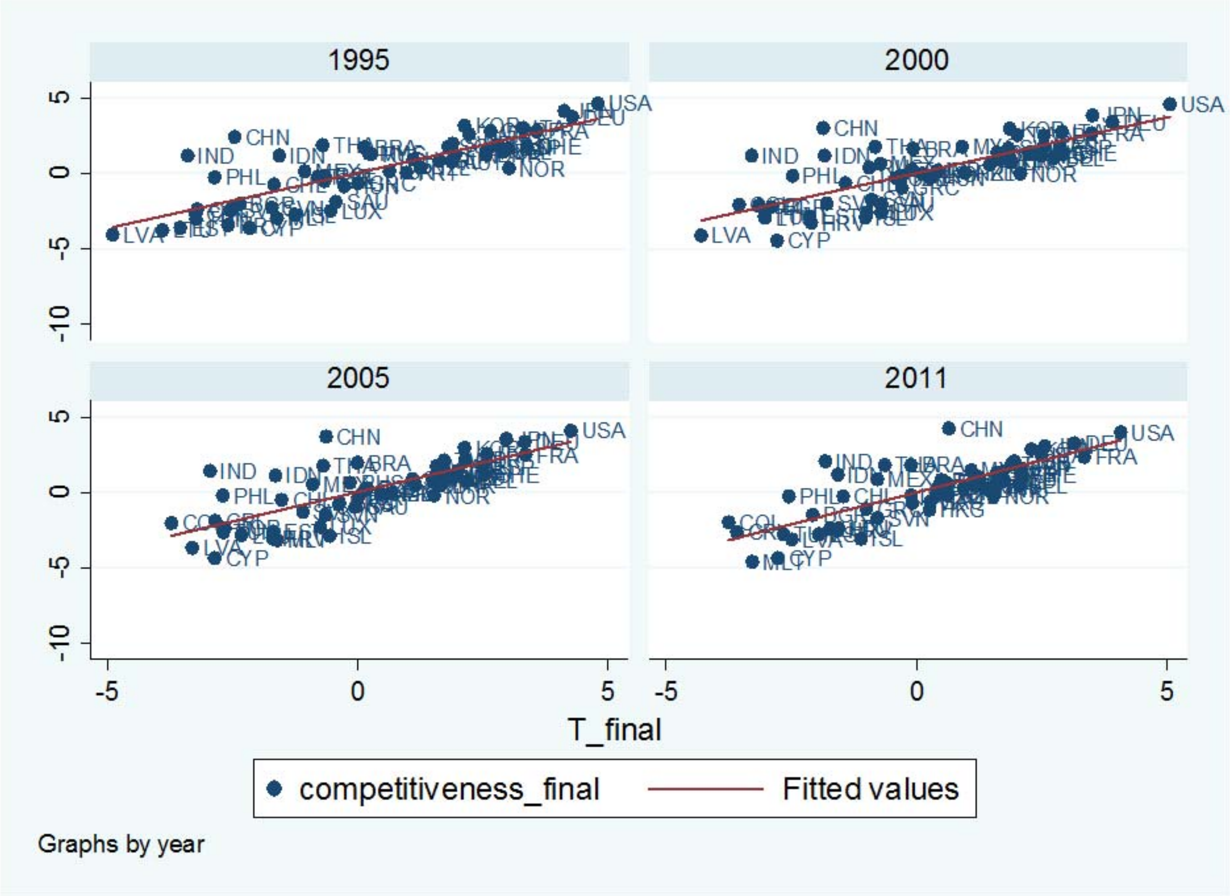

Figure 13: $\widetilde{D}_n$ (y-axis) vs. $\widetilde{T}_n$ (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.

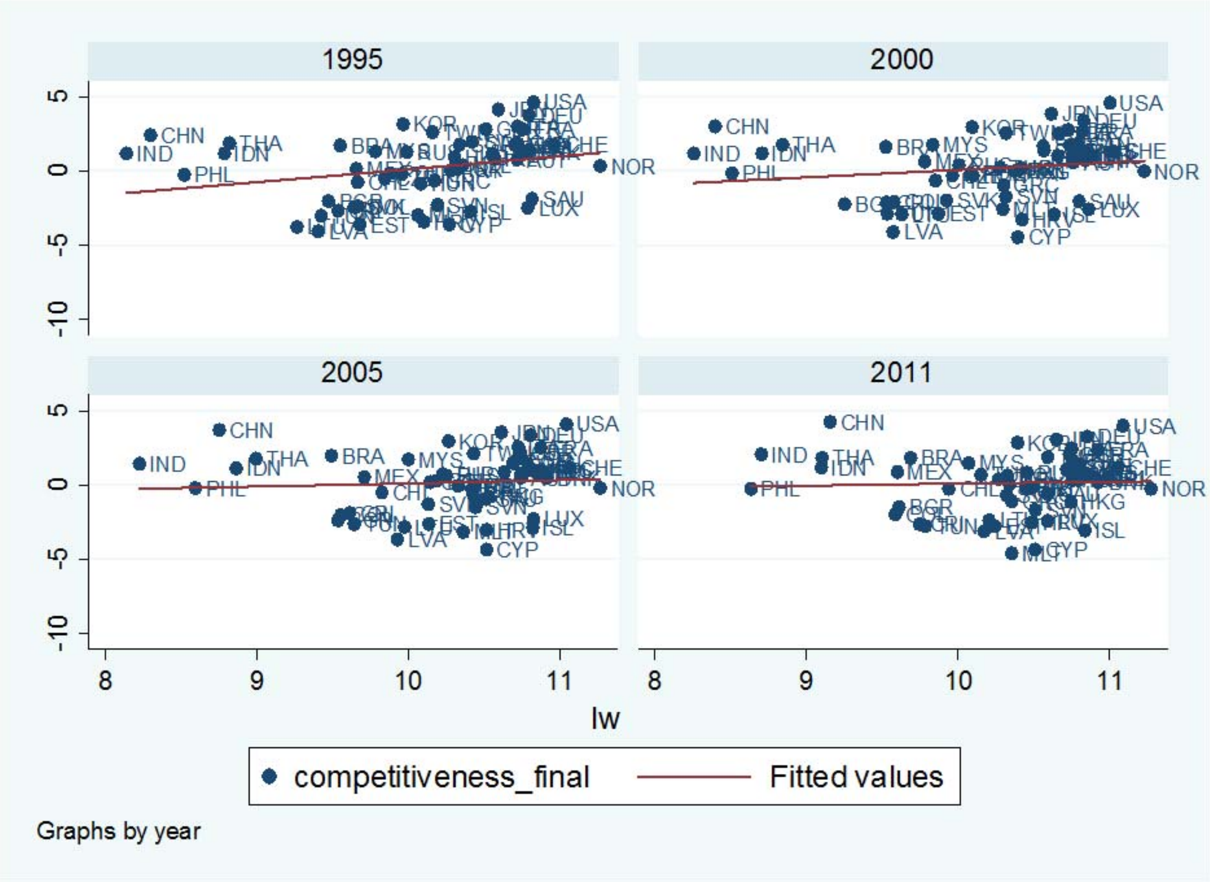

Figure 14: $\widetilde{D}_n$ (y-axis) vs. $\ln w_n$ (x-axis). For the estimated slope and statistical significance of each fitted line, refer to Appendix C.