The Pennsylvania State University
The Graduate School

ESSAYS IN INTERNATIONAL TRADE OF SERVICES AND STRUCTURAL TRANSFORMATION

A Dissertation in
Economics
by
Yesheng Guo

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

May 2017

The dissertation of Yesheng Guo was reviewed and approved* by the following:

James Tybout
Professor of Economics
Dissertation Advisor, Chair of Committee

Stephen Yeaple
Professor of Economics

Russell Cooper
Professor of Economics

David Abler
Professor of Agricultural, Environmental and Regional Economics

Barry W. Ickes
Professor of Economics
Department Head, Department of Economics

*Signatures are on file in the Graduate School.

Abstract

Services has long been the largest sector of the global economy. In 2011, it produced over 70% of the world's GDP and employed nearly 50% of the world's labor force. In the United States, those shares were around 80%. Meanwhile, total imports of services reached 6% of the worlds' GDP, almost 1/3 of total goods imports, and it has been steadily growing at 2.63% per annum since 1995, 54% faster than goods trade. Despite its solid presence, services trade is still missing in most existing trade studies. It is often taken as a closed outside sector whose main purpose is to complete the equilibrium. The goal of this thesis is to demonstrate the importance of services trade to our understanding of comparative advantage and welfare implications of trade. In particular, I will introduce services trade and related data sources, provide benchmark quantifications of the gains from services trade, investigate the evolution of comparative advantage of services industries over time, and discuss how trade in services can interact with market entry and technology to generate interesting labor reallocation across sectors.

The main results can be summarized as follows. First, standard gravity models fit services trade well. This allows us to apply the widely popular Eaton Kortum model to services and estimate services productivities. Second, in a series of counterfactual experiments, the same amount of technological progress or friction reduction in services will lead to 3 to 4 times higher gains from trade than in manufacturing. Next, by estimating productivities for 35

industries, 17 in services, from 1995 to 2000, we found that while comparative advantage was weakened in all sectors, relative convergence among services industries was 75% faster than manufacturing industries on average. Such convergence eliminated 3.9% potential gains from trade from the median country, and reduced total trade volume by 25%. In addition, we estimated the speed of technological diffusion across industries within each country to be 3.6% and that across countries for every industry to be 6.0%. Last but not least, inspired by the negative correlation between trade intensity and employment share found in the swift labor reallocation from manufacturing to services in the U.S. since 2000, we discussed how interactions between entry choice, skill-biased technology, and trade may give rise to interesting patterns of structural transformation.

This thesis offers basic quantifications of the macro impact of services trade on welfare and structural transformation. From these basic quantifications, we can infer that promoting services trade will unlock considerable amount of potential gains, much higher than the gains from goods trade. At the same time, strengthening services comparative advantage could further hurt employment in other sectors, particularly manufacturing. Fortunately, the manufacturing comparative advantage of the non-OECD countries has diminished in recent decades, reducing the relative cost of re-industrialization that US and other OECD countries are pursuing. Finally, as more granular services trade data becomes available, better economics and econometrics tools can be applied to improve our quantification and deepen our understanding of services trade for policy considerations.

Table of Contents

List of Figures

List of Tables

Acknowledgments

I am deeply indebted to my advisor James Tybout and Jonathan Eaton for their invaluable advice, knowledge and encouragement. This dissertation was also influenced and improved by the advice and guidance of Stephen Yeaple. I am grateful to my committee members, Russell Cooper and David Abler for their helpful comments and suggestions. I also benefited from discussions with Farid Farrokhi, Kai Li, and Rong Luo. Last but not least, I would like to thank my wife and my parents for their patience and support along this journey.

Dedication

To Yi Sui, Ying Shi and Zhen Guo.

Chapter 1

A General Equilibrium Model for Trade in Goods and Services

1.1 Introduction to Services Trade

Services has long been the largest sector of the global economy. In 2011, it produced over 70% of the world's GDP and employed nearly 50% of the world's labor force.[1] In the United States, those shares were 79% and 82% respectively.[2] Despite its dominating size, services just started to gain tractions in the studies of international trade. In 2011, total imports of services reached 6% of the world GDP, close to 1/3 of total goods imports. While globalization has not altered services production to the extent of manufacturing, services trade is rapidly gaining momentum. Average growth of services trade since 1995 is 2.63% per annum, 54% faster than goods trade.[3] In fact, policy makers already saw the potential gains in the international services market and are making services treaty into the standard package of trade negotiations. The goal of this thesis is to introduce services trade and related data sources, provide benchmark quantifications of the gains from services trade

[1]Data from the Penn World Table 8.1 maintained by the Groningen Growth and Development Centre

[2]Data from the World Bank.

[3]Data from the World Input-Output Database and OECD.

under general equilibrium settings, investigate the evolution of comparative advantage of services industries over time, and discuss how trade in services can impact labor reallocation across sectors.

The presence of services in the trade literature was limited by a major reason – *intangibility*. Since most services are intangible, they are not traded in the same fashion as goods. In many cases, the production and consumption of services are often inseparable in time and location. Such characteristics are very inconvenient for the definition and measurement of services trade. To standardize the scope and accounting of services flows, WTO defined four modes of supply in its introduction of the General Agreement on Trade in Services (GATS) in 1995:[4]

1. **Cross-border supply** is defined to cover services flows from the territory of one Member into the territory of another Member (e.g. banking or architectural services transmitted via telecommunications or mail);

2. **Consumption abroad** refers to situations where a service consumer (e.g. tourist or patient) moves into another Member's territory to obtain a service;

3. **Commercial presence** implies that a service supplier of one Member establishes a territorial presence, including through ownership or lease of premises, in another Member's territory to provide a service (e.g. domestic subsidiaries of foreign insurance companies or hotel chains); and

4. **Presence of natural persons** consists of persons of one Member entering the territory of another Member to supply a service (e.g. accountants, doctors or teachers). The Annex on Movement of Natural Persons specifies, however, that Members remain free to operate measures regarding citizenship, residence or access to the employment market on a permanent basis.

[4]More details on the description are available at www.wto.org/english/tratop_e/serv_e/gatsqa_e.htm.

While modes 1 and 2 weakly resemble the conventional definition of goods trade, modes 3 and 4 can be thought as the counterpart of manufacturing offshoring and FDI. GATS was well received by policy makers, most WTO members amended their existing goods treaties to cover services at least partially. In the meantime, several datasets have been created to record bilateral services flows that enable comparisons across countries and industries. Databases like OECD Statistics, UN Service Trade Statistics Database, and GTAP all maintain bilateral flows in modes 1 and 2 for services industries in major economies since 1995. They will be the primary data sources for the analysis in the first two chapters.

Incorporating services into a trade framework has two important implications. First, it allows for unconditioned interpretation of comparative advantage. Instead of limiting productivity comparisons within the manufacturing sector, it is now possible to analyze how changes in services productivity affects manufacturing trade patterns and vice versa. For instance, it can help us to endogenize the persistent goods deficits in north-south trade. If we take a snapshot of U.S. trade in 2009, it contributed nearly 14% of world's services exports but only absorbed 10% of the world's total imports. Services brought in $143.3 billion worth of trade surplus, enough to offset nearly 1/3 of the deficits from goods trade. In fact, U.S. has enjoyed sizeable services surplus for over a decade. Including services trade in this case will indubitably reduce the bias in our measurement of the comparative advantage. Second, it allows us to quantify the welfare gains and labor displacements unaccounted for in the existing literature. Because of its size, services sector weighs heavily in the determination of labor market outcomes. Not only is it a big buffer for wage and employment shocks induced by goods trade, as it actively competes with the goods sector in the labor market, services trade liberalization can also offer new insights to the interesting labor reallocation patterns across sectors.

While there are many additional reasons why services can be the important missing piece to complete the picture of global trade, it is not immediately clear if existing models built for goods trade are compatible with services. Does intangibility separate services trade from other sectors? Surprisingly, despite all the complications in the modes of supply and accounting, existing data has already revealed remarkable empirical similarities between goods and services trade at the macro level.

1.1.1 Gravity in Services Trade

Gravity is one of the most robust empirical regularities of goods trade. In its generic form, bilateral trade flow is proportional to the size of the origin and destination market, and inversely proportional to the trade frictions between the two markets. Let X_{ni} be the trade flow from country i to country n, Z_n and Z_i represent the destination and origin market characteristics, $\tau_{ni} \geq 1$ be a proxy for trade frictions between n and i. Simple gravity can be written as

$$X_{ni} = \kappa \frac{Z_n Z_i}{\tau_{ni}}.$$

To test for gravity in services trade, it is convenient to transform the above into the Head-Ries index introduced by Head and Ries (2001), which eliminates the need to estimate Z_n, Z_i or κ directly:

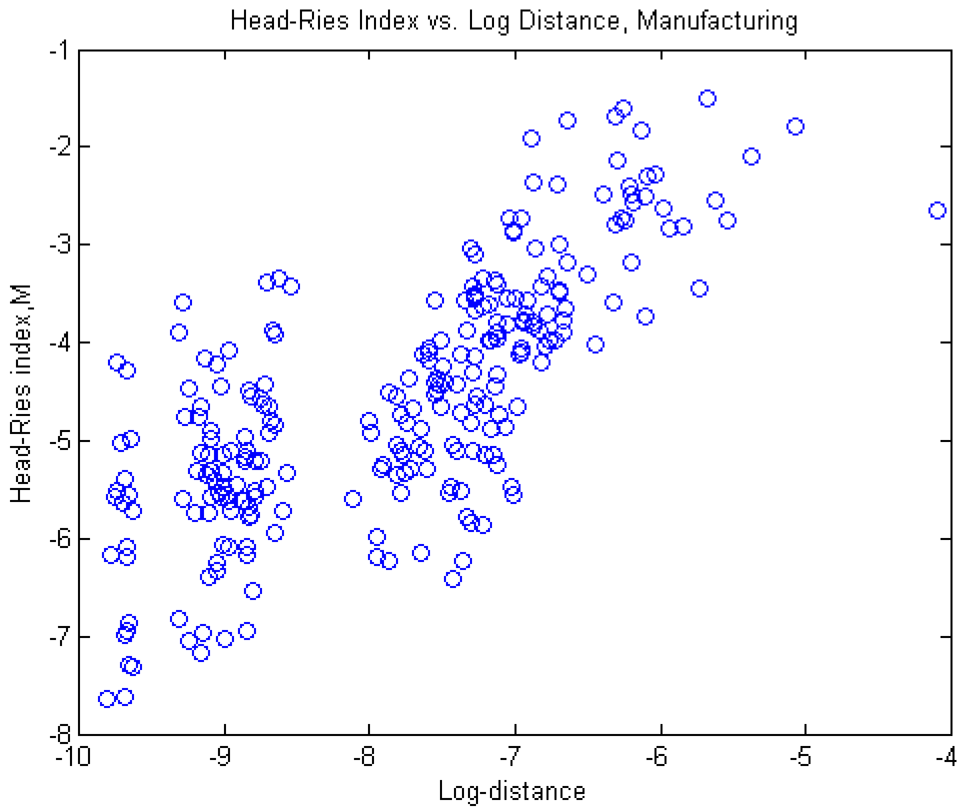
$$\zeta_{ni} = \left(\frac{X_{ni} X_{in}}{X_{nn} X_{ii}} \right)^{-\frac{1}{2}}.$$

With the additional assumption that $\tau_{ii} = 1$ for all countries and trade frictions between n and i are symmetric, the Head-Ries index can be further reduced into

$$\zeta_{ni} = (\tau_{ni} \tau_{in})^{\frac{1}{2}} = \tau_{ni}.$$

Using the logarithm of geographical distance as a rough proxy for τ_{ni}, if services trade satisfies gravity, the Head-Ries index ζ_{ni} should be a linear function of log distance.

Figure 1.1 and 1.2 plot the Head-Ries index of both manufacturing and services against



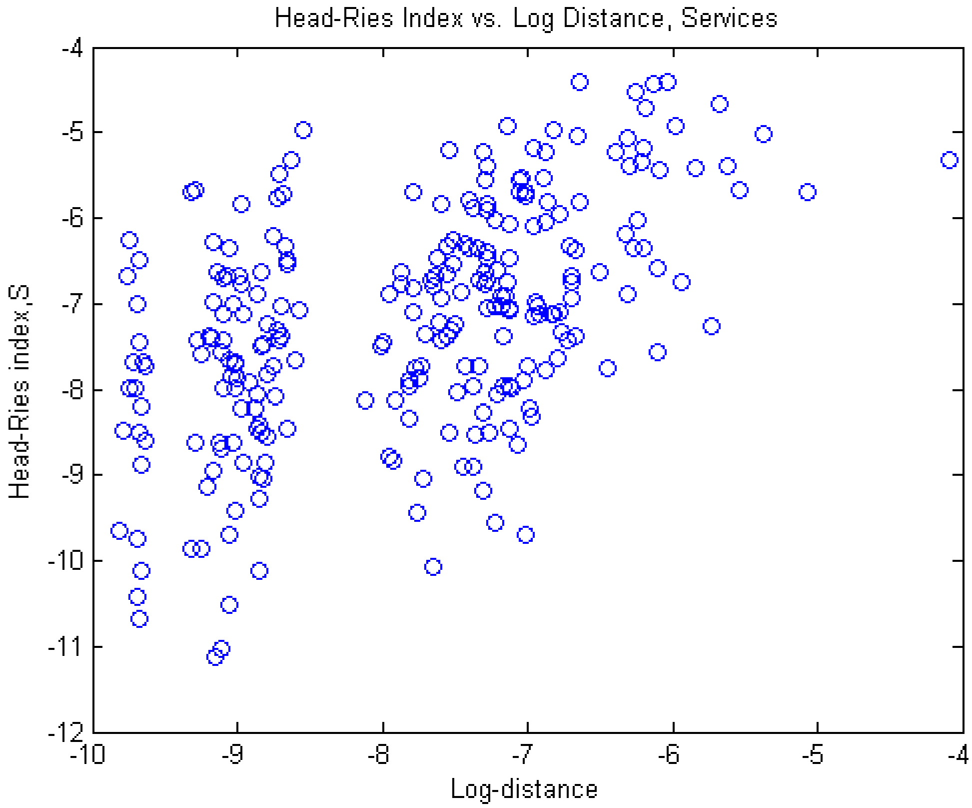
Source: OECD and CEPII Gravity Database.

Figure 1.1. Head-Ries Index against Log-Distance for Manufacturing Sector, 2008.

log distance using data from the OECD bilateral services trade data and CEPII gravity distance data for 23 OECD countries in 2008. Even though the fit for services flows is not as tight as that for manufacturing, the upward trend is inevitably clear. This finding is in line with a handful of existing studies in the literature.

1.1.2 Literature on Services Gravity

The existing literature on gravity in services trade is limited. Early reduced-form works by Francois (2001), Park (2002) and Francois et al. (2003) applied standard gravity model to services trade and estimated tariff equivalent trade frictions. The study by Grunfeld and



Source: OECD and CEPII Gravity Database.

Figure 1.2. Head-Ries Index against Log-Distance for Services Sector, 2008.

Moxnes (2003) based on OECD data confirmed that standard gravity effects found in goods trade also works well with services trade. Following their work, Kimura and Lee (2006) further compared the gravity results of services trade to goods trade. Similar comparisons done by Lejour and de Paiva Verheijden (2006) and Lennon (2006) suggested that distance is less important for services trade whereas common language is more important. Walsh (2006) presented a nice summary of the reduced-form works on gravity in services trade.

Besides the reduced-form studies, the structural branch appeared fairly recently. Anderson et al. (2010) structurally modelled gravity in services trade in a partial setting centered around the Canadian services sector. Francois et al. (2008) used simulations to estimate the existing services trade barriers in the EU and plugged them into a computable general equilibrium model to explain the specialization patterns of services among the EU countries. Nordas (2010) first used the input-output table to model the role of services in goods production and trade, as well as the impact of services trade liberalization on countries' industrial structure.

This chapter is most closely related to Egger et al. (2012), which structurally analyzed the effects of preferential trade liberalization of services and goods trade using a bi-sectoral general equilibrium model with linear production and constant elasticity of substitution (CES) demand. They explicitly modelled inter-temporal shocks and used trade data of 16 European OECD countries from 1999 to 2006 to conduct their estimation and counterfactuals. They found that services trade react more elastically to trade liberalizations than goods trade and services trade liberalization shifts labor from goods production to services production. This chapter adds more structure to their work. First, the input-output structure acknowledges the fact that a significant portion of output are intermediates fed back into production and there is significant technology spill-over embedded in these inputs. Second, the effect of productivity heterogeneity is explicitly modelled which enables direct estimation and comparison of the implied absolute and comparative advantages across countries.

In the rest of the chapter, I will introduce the general equilibrium model extended from Eaton and Kortum (2002). The model is estimated using the OECD bilateral services trade data for 23 OECD countries in 2008. Simple counterfactuals will be conducted in the end to test the elasticities of employment and wage to different types of trade friction and technological shocks.

1.2 The Model

The model is adapted from the general equilibrium model in Eaton et al. (2011), which is a multi-sectoral generalization of the Eaton and Kortum (2002) model aimed to study the collapse of trade in durable and nondurable goods during the 2008 global recession. An interesting feature of this model is the inter-sectoral input-output structure which enables cross-sectoral production and demand linkages. I will follow most of original notations and start by describing the input-output structure.

1.2.1 The Input-Output Structure

Consider a perfectly competitive world with I countries indexed by i or n. Production in each country is constant return to scale and divided into three broad sectors indexed by $j \in \Omega = \{M, S, R\}$, where M stands for manufacturing, S for services and R for all the remaining sectors. Since the focus is on M and S, sector R is assumed to be exogenous and will be substituted out of the equilibrium equations during the estimation process. Suppose labor is the only factor of production and denote each country's endowment by L_i. Further assume that labor is perfectly mobile across sectors but immobile across countries. Perfect competition therefore implies a single wage w_i in each country.

Let X_{ij} and Y_{ij} be the value of gross absorption and production of sector j in country i. Sectoral deficits are defined as $D_{ij} = X_{ij} - Y_{ij}$. Country i's total trade deficit is thus $D_i = \sum_{j \in \Omega} D_{ij}$. Denote by Y_i^F and X_i^F the GDP and aggregate final spending in i. By definition,

$$X_i^F = Y_i^F + D_i.$$

Also assume that all output of a sector can either be used as final consumption or intermediate inputs for the production of other sectors. There is no inter-temporal savings in this model.

The input-output structure in this model is a Cobb-Douglas aggregator that combines labor and intermediates into an input bundle. It can be fully characterized by a set of shares. Let α_{ij} denote the share of sector j in country i's final demand, β_{ij} be the share of labor value-added in the gross production of j in i, and γ_{ijl} be the share of intermediates from sector l in total intermediates used in the production of j in i. Note that $\sum_{j\in\Omega}\alpha_{ij}=1$ and $\sum_{l\in\Omega}\gamma_{ijl}=1$ for all i and j. These shares establish the following link between production and consumption for each i and j,

$$\begin{aligned} X_{ij} =& \alpha_{ij}X_i^F + \sum_{l\in\Omega}\gamma_{ilj}\left(1-\beta_{il}\right)Y_{il} \\ =& \alpha_{ij}\left(Y_i^F + D_i\right) + \sum_{l\in\Omega}\gamma_{ilj}\left(1-\beta_{il}\right)\left(X_{il}-D_{il}\right), \end{aligned} \tag{1.1}$$

and

$$Y_i^F = w_iL_i = w_i\sum_{j\in\Omega}L_{ij} = \sum_{j\in\Omega}\beta_{ij}Y_{ij}. \tag{1.2}$$

The first term on the right hand side of the 1.1 captures the amount of sector j output consumed as final demand and the second term captures the amount used as intermediates in the production of all other sectors. Their sum must be i's total spending on sector j. Moreover, let P_{ij} be the sectoral price index of j in i. The cost of the input bundle of j in i implied by this input-output structure can be written as

$$c_{ij} = w_i^{\beta_{ij}}\prod_{l\in\Omega}\left(P_{il}\right)^{(1-\beta_{ij})\gamma_{ijl}}. \tag{1.3}$$

1.2.2 The Eaton-Kortum Model for Trade

Assume each sector has a continuum of varieties $q\in[0,1]$ that is common to all countries. Demand over these varieties is CES with a sector-specific elasticity $\sigma_j>0$, which can also be interpreted as demand of a sectoral composite good produced by all varieties using the production function

$$Q_{ij} = \left[\int_q Q_{ij}(q)^{\frac{\sigma_j-1}{\sigma_j}}dq\right]^{\frac{\sigma_j}{\sigma_j-1}}.$$

The corresponding price index of this composite is

$$P_{ij} = \left[\int_q p_{ij}(q)^{1-\sigma_j} dq \right]^{\frac{1}{1-\sigma_j}},$$

where $p_{ij}(q)$ is the price of variety q of sector j in country i. Productivity of every variety is assumed to be an independent draw from a Frechet distribution

$$F_{ij}(z) = \exp\left(-T_{ij} z^{-\theta_j}\right),$$

where $T_{ij} > 0$ represents i's overall efficiency in sector j and the inverse of $\theta_j > 1$ captures the dispersion of productivities across varieties. Average productivity of sector j in i is given by $T_{ij}^{\frac{1}{\theta_j}}$.

Let $d_{nij} \geq 1$ be iceberg trade frictions of sector j products between n and i with $d_{iij} = 1$ for all i and j. The unit price of a z_j variety imported from i to n is

$$p_{nij}(z_j) = \frac{c_{ij} d_{nij}}{z_j}. \tag{1.4}$$

Perfect competition implies that the lowest-priced source wins the market, i.e.

$$p_{nj}(z_j) = \min_{i=1,..,I} \{p_{nij}(z_j)\}.$$

Following Eaton and Kortum (2002), the above leads to the well-known price index for sector j in country n

$$P_{nj} = \Gamma_j \left[\sum_{i=1}^{I} T_{ij} \left(c_{ij} d_{nij}\right)^{-\theta_j} \right]^{-\frac{1}{\theta_j}}, \tag{1.5}$$

where $\Gamma_j = \Gamma\left(\frac{\theta_j + 1 - \sigma_j}{\theta_j}\right)^{\frac{1}{1-\sigma_j}}$ and $\theta_j > \sigma_j - 1$ must hold for it to exist.

Let π_{nij} be the share of country n's expenditures on sector j outputs from country i and

X_{nij} be the actual trade flow. Then π_{nij} can be expressed as

$$\pi_{nij} = \frac{X_{nij}}{X_{nj}} = \frac{T_{ij}\left(c_{ij}d_{nij}\right)^{-\theta_j}}{\sum_{k=1}^{I} T_{kj}\left(c_{kj}d_{nkj}\right)^{-\theta_j}}. \tag{1.6}$$

In addition, the trade flows must satisfy the market clearing condition

$$Y_{ij} = \sum_{n=1}^{I} \pi_{nij} X_{nj}. \tag{1.7}$$

Note that gravity is embedded in this model since

$$\zeta_{nij} = \left(\frac{X_{nij}X_{inj}}{X_{iij}X_{nnj}}\right)^{-\frac{1}{2}} = \left(d_{nij}d_{inj}\right)^{\frac{\theta_j}{2}}$$

which shares the form of the simple Head-Ries Index presented in Section 1.1.1.

The global equilibrium of the model is characterized following Alvarez and Lucas (2007), Dekle et al. (2008), and Eaton et al. (2011). Set the world GDP as the numeraire. Given the labor force L_i in each country, the demand parameters α_{ij} and σ_j, the input-output parameters β_{ij} and γ_{ilj}, the productivity distribution T_{ij} and θ_j, sectoral trade deficits D_{ij}, and frictions d_{nij}, the global equilibrium is a set of wages w_i, prices p_{ij} and trade flows X_{nij} that jointly solve equations 1.1, 1.2, 1.5, 1.6 and 1.7.

While many parameters are readily available in data, three unobservable must be estimated – the productivity distribution T_{ij}, θ_j and the trade frictions d_{nij}. In the following section, these parameters will be estimated using the OECD bilateral trade dataset.

1.3 Model Estimation

The model is estimated in three steps. I will start by substituting out the irrelevant sectors to focus on manufacturing and services, which are the two sectors of interests. Next, a proxy for trade frictions is constructed to simplify estimation. Finally, the unobserved parameters are estimated using a two-step generalized least squares method.

1.3.1 Substituting Out Other Sectors

Since the primary focus is on manufacturing and services, it is convenient to fold up the remaining sectors following Eaton et al. (2011). Recall that R denotes all other sectors that are not manufacturing or services. Assume that production technology of varieties in R is homogeneous, and denote this country-specific productivity by A_{iR}. The price index of R can thus be rewritten as $P_{iR} = c_{iR}/A_{iR}$. Expanding P_{iR} using the cost function 1.3 yields

$$P_{iR} = \left[\frac{w_i^{\beta_{iR}}}{A_{iR}} \prod_{j \in \{M,S\}} P_{ij}^{\gamma_{iRj}(1-\beta_{iR})} \right]^{\frac{1}{1-\gamma_{iRR}(1-\beta_{iR})}}$$

Substituting the above back into the cost function 1.3 for $j = M, S$ results in

$$c_{ij} = \frac{w_i^{\beta_{ij}}}{\tilde{A}_{ij}} \prod_{l \in \{M,S\}} P_{il}^{\tilde{\gamma}_{ijl}(1-\tilde{\beta}_{ij})}, \tag{1.8}$$

where

$$\begin{aligned} \tilde{A}_{ij} =& (A_{iR})^{\frac{\gamma_{ijR}(1-\beta_{ij})}{1-\gamma_{iRR}(1-\beta_{iR})}}, \\ \tilde{\beta}_{ij} =& \beta_{ij} + \frac{\gamma_{ijR}(1-\beta_{ij})\beta_{iR}}{1-\gamma_{iRR}(1-\beta_{iR})}, \\ \tilde{\gamma}_{ijl} =& \gamma_{ijl} + \gamma_{ijR}\frac{\gamma_{iRl}(1-\beta_{iR}) + \gamma_{ijl}\beta_{iR}}{1-\gamma_{iRR}(1-\beta_{iR}) - \gamma_{ijR}\beta_{iR}}. \end{aligned}$$

$\tilde{A}_{ij}$ captures the effect of productivity of R on the input costs of M and S, $\tilde{\beta}_{ij}$ contains both the direct value-added in sector j and the indirect value-added embodied in R intermediates used in sector j. The folded $\tilde{\gamma}_{ijl}$ still satisfies $\sum_{j \in \{M,S\}} \tilde{\gamma}_{ijl} = 1$. Applying the folded input-output shares to equation 1.1 yields

$$X_{ij} = \tilde{\alpha}_{ij}\left(Y_i^F + D_i\right) - \tilde{\lambda}_{ij} D_{iR} + \sum_{l \in \{M,S\}} \tilde{\gamma}_{ilj}\left(1 - \tilde{\beta}_{il}\right) Y_{il}, \tag{1.9}$$

where

$$\begin{aligned}\tilde{\alpha}_{ij} =& \alpha_{ij} + \tilde{\lambda}_{ij}\alpha_{iR},\\ \tilde{\lambda}_{ij} =& \frac{\gamma_{iRJ}(1-\beta_{iR})}{1-\gamma_{iRR}(1-\beta_{iR})}.\end{aligned}$$

Equations 1.9 and 1.8 replaces equation 1.1 and 1.3 in the relevant equilibrium conditions. As a result, except for R's trade deficits D_{iR} which are treated as exogenous, we can limit our attention to only data related to M and S.

1.3.2 Constructing Proxies for Trade Frictions

The proxy for trade frictions d_{nij} is constructed as in Egger et al. (2012), Eaton and Kortum (2002) and many other gravity related works. It incorporates dummy variables for geographic proximity, language, colonial ties, trade agreements. In particular, for $i \neq n$, let

$$\ln d_{nij} = dt_{knij} + bd_{nij} + la_{nij} + cl_{nij} + ta_{nij} + s_{ij} + m_{nj} + \epsilon_{nij}, \tag{1.10}$$

where dt_{knij}, $k = 1, ..., 6$, is the effect of distance in the k-th bin, bd_{nij} measures the effect of sharing borders, la_{nij} is the effect of common language, cl_{nij} is the effect of colonial ties, ta_{nij} is the effect of trade agreements, s_{ij} and m_{nj} are the exporter and importer fixed effects respectively. The last term ϵ_{nij} represents the trade barrier due to other unaccounted effects. The six distance bins are $[0, 375)$, $[375, 750)$, $[750, 1500)$, $[1500, 3000)$, $[3000, 6000)$ and $[6000, \infty)$ in miles. To account for the potential correlation between residuals ϵ_{nij} and

ϵ_{inj}, I further decomposed the residual term into a directional part and a reciprocal part

$$\epsilon_{nij} = \epsilon_{nij1} + \epsilon_{nij2},$$

where ϵ_{nij1} with variance σ_{j1}^2 only affects the one-way trade from i to n, while ϵ_{nij2} with variance σ_{j2}^2 affects two-way trade so that $\epsilon_{nij2} = \epsilon_{inj2}$. As a result, the variance-covariance matrix for ϵ_{nij} and ϵ_{inj} has $\sigma_{j1}^2 + \sigma_{j2}^2$ on the diagonal and σ_{j2}^2 off the diagonal.

1.3.3 General Least Squares Estimation

With the above construction for d_{nij}, θ_j can be identified by prices. Expand equation 1.6 using the folded cost function 1.8 and apply it to country pairs $n - i$ and $i - i$ yields

$$\begin{aligned} \pi_{nij} &= \left[w_i^{\tilde{\beta}_{ij}} P_{ij}^{\tilde{\gamma}_{ijj}(1-\tilde{\beta}_{ij})} P_{il}^{\tilde{\gamma}_{ijl}(1-\tilde{\beta}_{ij})} \frac{\Gamma_j d_{nij}}{\tilde{T}_{ij} P_{nj}} \right]^{-\theta j}, \\ \pi_{iij} &= \left[w_i^{\tilde{\beta}_{ij}} P_{ij}^{\tilde{\gamma}_{ijj}(1-\tilde{\beta}_{ij})} P_{il}^{\tilde{\gamma}_{ijl}(1-\tilde{\beta}_{ij})} \frac{\Gamma_j}{\tilde{T}_{ij} P_{ij}} \right]^{-\theta j}, \end{aligned} \tag{1.11}$$

where $\tilde{T}_{ij} = \tilde{A}_{ij} T_{ij}^{1/\theta_j}$ are the augmented efficiency levels adjusted for the production efficiency in other sectors. Taking their ratio results in

$$\frac{\pi_{nij}}{\pi_{iij}} = \left(\frac{P_{ij} d_{nij}}{P_{nj}} \right)^{-\theta_j}. \tag{1.12}$$

θ_j is identified if appropriate price ratios are available. Note that the normalized trade share in the above equation cannot exceed 1, which requires that d_{nij} satisfies the no-arbitrage condition $P_{ij} d_{nij} \geq P_{nj}$.

Combining equations 1.10 and 1.12 produces the GLS estimation equation

$$\ln\frac{\pi_{nij}}{\pi_{iij}} = -\theta_j \ln\frac{P_{ij}}{P_{nj}} - \theta_j \left(dt_{knij} + bd_{nij} + la_{nij} + cl_{nij} + ta_{nij} + s_{ij} + m_{nj} + \epsilon_{nij}\right). \quad (1.13)$$

A two-step GLS is implemented. First, the residuals from a simple OLS estimation of the above equation are extracted to estimate the variance-covariance structure for ϵ_{nij}. Second, GLS is run using the estimated variance-covariance matrix.

This approach presumes that approriate price indices are observable. In actual estimation, the price indices used are constructed from producer price indices for manufactured goods, consumer price indicies of services products, as well as price level for expenditures for major industries and product categories in benchmark purchasing power parities from OECD.Stats database. These price indicies are proxies of P_{nj} in the model. In addition, this approach is also prone to simultaneity as trade shares and price ratios are both equilibrium outcomes. When estimating θ, lagged price indices from 2005 are used as instruments attempting to reduce the simultaneity bias.

The three unobservable are obtained from the estimation results. θ_j can be directly read from the coefficients, d_{nij} can be backed out using θ_j and the remaining coefficients, and $\tilde{T}_{ij}$ can be imputed from the second equation in 1.11. However, doing so does not fully utilize the available degrees of freedom offered by the data and may result in skewed estimates for $\tilde{T}_{ij}$. To avoid solving for the I $\tilde{T}_{ij}$'s from I equations, consider an alternative normalization

$$\begin{aligned} \pi_{nij} &= \left[w_i^{\tilde{\beta}_{ij}} P_{ij}^{\tilde{\gamma}_{ijj}(1-\tilde{\beta}_{ij})} P_{il}^{\tilde{\gamma}_{ijl}(1-\tilde{\beta}_{ij})} \frac{\Gamma_j d_{nij}}{\tilde{T}_{ij} P_{nj}} \right]^{-\theta j}, \\ \pi_{nnj} &= \left[w_n^{\tilde{\beta}_{nj}} P_{nj}^{\tilde{\gamma}_{njj}(1-\tilde{\beta}_{nj})} P_{nl}^{\tilde{\gamma}_{njl}(1-\tilde{\beta}_{nj})} \frac{\Gamma_j}{\tilde{T}_{nj} P_{nj}} \right]^{-\theta j}, \end{aligned} \quad (1.14)$$

and define the country specific effects as

$$\Lambda_{ij} = \left[w_i^{\tilde{\beta}_{ij}} P_{ij}^{\tilde{\gamma}_{ijj}(1-\tilde{\beta}_{ij})} P_{il}^{\tilde{\gamma}_{ijl}(1-\tilde{\beta}_{ij})} \frac{\Gamma_j}{\tilde{T}_{ij}} \right]^{-\theta j}. \tag{1.15}$$

We have an alternative estimation equation

$$\ln \frac{\pi_{nij}}{\pi_{nnj}} = -\theta_j \ln d_{nij} + \Lambda_{ij} - \Lambda_{nj}, \tag{1.16}$$

which exploits the degrees of freedom in the data to smooth the country fixed effects and produce a more reliable estimation of trade frictions d_{nij}. The final estimates for $\tilde{T}_{ij}$ and d_{nij} are imputed from the smoothed country fixed effect using equation 1.15 and the estimate for θ_j obtained from equation 1.13.

1.4 Numerical Results and Counterfactuals

In this section, I will estimate the model using bilateral trade and price data for 23 OECD countries in 2008. Detailed description of the data can be found in Appendix A. A snapshot of the data is shown in table 1.1. On average, within-the-sample trade accounts for about 64% of the total manufacturing trade and 62% of services in 2008. However, the share of services trade in GDP is much lower than manufacturing. Given that services production is on average 2.4 times larger than manufacturing, only about 8% of total services output is traded. Average ratio of services imports over GDP is only 10% whereas that for manufacturing is 30%.

Country	In-Sample Trade M	In-Sample Trade S	Trade/GDP* M	Trade/GDP* S	Price Level M	Price Level S	Gross Output S/M	GDP♮
Australia	45%	46%	16%	4%	139	121	3.9	1053
Austria	70%	63%	37%	10%	136	116	2.1	414
Canada	78%	69%	23%	6%	126	120	3.1	1503
Czech	77%	74%	55%	8%	112	64	1.3	225
Denmark	66%	57%	30%	18%	170	159	3.4	344
Finland	63%	54%	26%	11%	147	144	1.7	272
France	62%	64%	21%	5%	137	133	2.8	2832
Germany	58%	64%	25%	8%	138	113	1.6	3624
Greece	57%	65%	21%	7%	115	101	3.9	342
Hungary	67%	64%	61%	12%	103	62	1.4	154
Ireland	69%	60%	27%	32%	144	152	2.1	264
Italy	58%	58%	18%	6%	123	116	2.0	2307
Japan	42%	48%	9%	3%	141	104	1.7	4849
Korea	39%	43%	31%	10%	87	63	0.9	931
Norway	73%	78%	19%	10%	181	154	3.2	454
Poland	71%	67%	34%	6%	113	61	1.8	529
Portugal	72%	64%	29%	7%	114	89	2.8	252
Slovak	80%	80%	64%	9%	110	60	1.3	98
Slovenia	65%	54%	58%	9%	109	84	1.9	55
Spain	65%	65%	21%	7%	115	108	2.7	1593
Sweden	71%	64%	29%	11%	149	129	2.1	486
U.K.	62%	66%	20%	8%	129	118	4.3	2649
U.S.	45%	57%	11%	3%	100	100	3.4	14219

Note: *Trade share is measured by imports/GDP. ♮GDP is shown in billions of USD.

Table 1.1. Data Summary

1.4.1 GLS Estimation Results

Table 1.2 presents the results of the GLS estimation of equation 1.13, with standard errors in parentheses. Table 1.3 presents the results of the alternative bilateral trade equation 1.16 in comparison to the initial GLS estimates. The related importer and exporter fixed effects are summarized in table 1.4. Results are significant for most variables except for the common language effect in services trade. As one would expect, the estimate for θ_M is consistent with the existing results in the literature. A comparison between the productivity dispersion of

Variable	Label	Manufacturing Est.	Manufacturing S.E.	Services Est.	Services S.E.
Productivity Dispersion	θ_j	5.33	(0.794)	9.38	(1.561)
Shared Border	bd_j	-0.07	(0.025)	-0.07	(0.018)
Common Language	la_j	-0.08	(0.029)	-0.01	(0.021)
Colonial Ties	cl_j	-0.06	(0.026)	-0.05	(0.019)
Trade Agreements	ta_j	-0.18	(0.043)	-0.05	(0.035)
Distance [0,375)	dt_{1j}	0.27	(0.068)	0.30	(0.050)
Distance [375,750)	dt_{2j}	0.44	(0.064)	0.41	(0.048)
Distance [750,1500)	dt_{3j}	0.54	(0.064)	0.44	(0.049)
Distance [1500,3000)	dt_{4j}	0.58	(0.069)	0.47	(0.052)
Distance [3000,6000)	dt_{5j}	0.70	(0.038)	0.54	(0.027)
Distance [6000,∞)	dt_{6j}	0.76	(0.043)	0.58	(0.031)
Adj. R^2 Manufacturing	0.8624	Error Variance		M	S
Adj. R^2 Services	0.8134	Two-Way (σ^2_{j2})		0.0074	0.0041
Valid observations	506	One-Way (σ^2_{j1})		0.0032	0.0013

Table 1.2. GLS Estimation of Bilateral Trade Equation 1.13

Variable	Label	Manufacturing Eqn.1.13	Manufacturing Eqn.1.16	Services Eqn.1.13	Services Eqn.1.16
Productivity Dispersion	θ_j	5.33	–	9.38	–
Shared Border	bd_j	-0.07	-0.07	-0.07	-0.07
Common Language	la_j	-0.08	-0.08	-0.01	-0.01
Colonial Ties	cl_j	-0.06	-0.06	-0.05	-0.05
Trade Agreements	ta_j	-0.18	-0.18	-0.05	-0.05
Distance [0,375)	dt_{1j}	0.27	0.60	0.30	0.57
Distance [375,750)	dt_{2j}	0.44	0.76	0.41	0.68
Distance [750,1500)	dt_{3j}	0.54	0.87	0.44	0.71
Distance [1500,3000)	dt_{4j}	0.58	0.91	0.47	0.74
Distance [3000,6000)	dt_{5j}	0.70	1.02	0.54	0.81
Distance [6000,∞)	dt_{6j}	0.76	1.08	0.58	0.85
Adj. R^2 Manufacturing	0.8627	Error Variance		M	S
Adj. R^2 Services	0.8138		Two-Way (σ^2_{j2})	0.0075	0.0041
Valid observations	506		One-Way (σ^2_{j1})	0.0032	0.0012

Table 1.3. GLS Estimation of Alternative Bilateral Trade Equation 1.16

Country	Manufacturing Importer	Manufacturing Exporter	Services Importer	Services Exporter
Australia	0.1600	0.1847	0.1374	0.1121
Austria	0.3517	0.1013	0.1451	0.2450
Canada	0.1818	0.0687	0.1786	0.0988
Czech	0.1825	0.4138	-0.3964	0.9389
Denmark	0.4922	-0.1454	0.3881	-0.1022
Finland	0.3853	0.1399	0.3085	0.0830
France	0.3793	-0.0801	0.3456	-0.0475
Germany	0.3629	-0.2698	0.1042	0.0454
Greece	0.1513	0.6871	0.0276	0.3482
Hungary	0.0356	0.3636	-0.5218	0.9463
Ireland	0.3975	0.1390	0.3197	-0.1694
Italy	0.3028	0.0408	0.1837	0.1006
Japan	0.4523	-0.2724	0.0875	0.1765
Korea	-0.0997	0.2890	-0.5481	0.7811
Norway	0.6213	0.0455	0.4060	-0.0137
Poland	0.1574	0.3480	-0.4458	0.9304
Portugal	0.1430	0.5197	-0.0626	0.5837
Slovak	0.1252	0.4226	-0.4941	1.0928
Slovenia	0.0956	0.6464	-0.1310	0.8228
Spain	0.1727	0.2153	0.1291	0.2001
Sweden	0.3713	-0.0135	0.1970	0.1019
U.K.	0.2522	-0.0122	0.1729	-0.0072
U.S.	-0.0044	-0.0117	-0.0023	-0.0068

Table 1.4. Importer and Exporter Fixed Effects in Equation 1.13

M and S indicates that productivity is less heterogeneous in services, which means weaker comparative advantage and less incentive to trade, one of the factors behind the observed low trade volume in services. In addition, services trade seems to be less sensitive to preferential trade agreements compared to goods trade, which is the exact opposite of what Egger et al. (2012) concluded in their analysis. Last but not least, while the trade diminishes as distance increases, services trade appears to be less hindered by larger geographical separation, consistent with the fact that the supply of many tradable services bypasses the increasing shipping costs over longer distances.

	Manufacturing		Services	
Country	Eqn.1.11	Eqn.1.15	Eqn.1.11	Eqn.1.15
Australia	0.81	0.67	0.90	0.80
Austria	0.76	0.68	0.97	0.75
Canada	0.78	0.72	0.84	0.76
Czech	0.68	0.44	0.95	0.37
Denmark	0.72	0.82	0.89	0.99
Finland	0.87	0.75	0.87	0.79
France	0.90	0.96	0.88	0.92
Germany	0.81	1.04	0.91	0.86
Greece	0.73	0.37	0.81	0.57
Hungary	0.57	0.39	0.85	0.33
Ireland	0.88	0.76	0.91	1.07
Italy	0.92	0.88	0.93	0.84
Japan	0.81	1.04	0.87	0.72
Korea	0.80	0.60	0.85	0.39
Norway	0.93	0.88	1.15	1.16
Poland	0.55	0.38	0.80	0.32
Portugal	0.66	0.39	0.75	0.41
Slovak	0.54	0.35	0.89	0.30
Slovenia	0.63	0.33	0.87	0.38
Spain	0.85	0.67	0.84	0.69
Sweden	0.81	0.81	0.93	0.83
U.K.	0.79	0.79	0.89	0.89
U.S.	1.00	1.00	1.00	1.00

Table 1.5. Implied State of Technology, $\tilde{T}_{ij}$

As discussed in section 1.3.3, equaltion 1.13 suffers from simultaneity bias. To alleviate the bias, price indices in 2005 are constructed as instruments for 2008 price indices. The resulting 2SLS estimation produces slightly higher estimates for θ_M and θ_S of 6.72 and 9.97 respectively. The rest of the conclusion still holds.

Table 1.5 lists the state of technology obtained from both equation 1.11 and 1.15 in each country in the sample. It is normalized so that the relevant U.S. measure is 1. In the initial GLS estimation, Norway is closest to the U.S. in terms of manufacturing and surpasses U.S. in terms of services. Well-recognized manufacturing giants like Germany and Japan do not stand out as one would expect. The corresponding measures in the alternative estimation are more reasonable. First, it corrects the low variation in services technology across countries due to the close-to-one domestic absorption of services production in all countries. Second, services efficiency is now more correlated with manufacturing productivity. Moreover, Germany and Japan in this case do excel in manufacturing as found in similar studies. On the services side, Ireland joins Norway and U.S. as the best services producing countries.

With the estimates for $\tilde{T}_{ij}$ and θ_j and proxies for d_{nij}, we can now proceed to carry out counterfactual experiments to quantify the gains from adopting trade agreements, reducing general trade frictions, and improving the state of technology and the resulting labor reallocation across sectors.

1.4.2 Counterfactuals

In this section, a series of counterfactual experiments will be analyzed to quantify the effect of various shocks on the equilibrium outcomes of the model. In particular, I will look at changes in prices, real wage, production, employment and trade shares. Since the labor endowment is L_i is exogenously fixed, any change in the total welfare is equivalent to change in the real wage. To solve for the counterfactual equilibrium, I use an iterative algorithm described in Appendix B. Due to the lack of data on the residual world to fully solve the equilibrium, I also treat the trade between sample countries and the rest of the world as fixed. All shocks analyzed can be summarized by changes in either d_{nij} or $\tilde{T}_{ij}$. To obtain the baseline outcomes, I first feed the estimated values of d_{nij} or $\tilde{T}_{ij}$ to the algorithm, and then compare the results solved using the counterfactual $\hat{d}_{nij}$ or $\hat{\tilde{T}}_{ij}$ against the baseline outcomes.

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	0.28	0.42	-0.14	0.01	0.38	0.41	0.42	0.02
Austria	0.39	0.45	-0.06	-0.01	0.37	0.44	0.45	0.04
Canada	-0.99	0.55	-1.02	0.52	0.11	0.09	0.03	-0.07
Czech	0.49	0.47	0.01	-0.01	0.36	0.45	0.48	0.07
Denmark	0.39	0.43	-0.06	-0.01	0.37	0.43	0.45	0.03
Finland	0.36	0.41	-0.12	-0.07	0.39	0.46	0.48	0.04
France	0.45	0.42	0.01	-0.02	0.34	0.43	0.45	0.04
Germany	0.45	0.47	0.01	0.03	0.36	0.43	0.46	0.05
Greece	0.47	0.43	0.02	-0.02	0.40	.044	0.45	0.04
Hungary	0.41	0.48	-0.05	0.03	0.37	0.43	0.46	0.05
Ireland	0.34	0.52	-0.07	0.10	0.38	0.41	0.41	0.01
Italy	0.53	0.46	0.12	0.05	0.33	0.39	0.40	0.03
Japan	3.15	2.22	0.70	-0.21	1.38	2.26	2.44	0.38
Korea	1.19	1.00	0.14	-0.05	0.78	0.98	1.05	0.14
Norway	0.52	0.52	0.07	0.07	0.40	0.44	0.45	0.03
Poland	0.47	0.77	0.01	-0.00	0.37	0.43	0.45	0.05
Portugal	0.39	0.40	-0.07	-0.06	0.37	0.44	0.46	0.04
Slovak	0.42	0.47	-0.06	-0.01	0.37	0.45	0.48	0.07
Slovenia	0.39	0.43	-0.05	-0.01	0.36	0.42	0.44	0.05
Spain	0.47	0.41	0.06	-0.01	0.34	0.40	0.42	0.03
Sweden	0.48	0.48	0.05	0.04	0.38	0.42	0.43	0.03
U.K.	0.36	0.43	-0.07	0.00	0.37	0.41	0.43	0.02
U.S.	0.13	0.23	0.42	-0.04	-0.31	0.22	0.30	0.18

Note: Numbers show changes in percentage points.

Table 1.6. Effect of U.S. - Japan Treaty, Manufacturing Only

1.4.2.1 Regional Trade Agreement

Let us start by examining the effect of adopting regional trade agreements. I will conduct three experiments to study the significance of different types of treaties, namely goods only, services only, and comprehensive. In addition, I will also present the extreme scenario where comprehensive treaties are signed between every pair of countries. The result will be reported in tables 1.6 through 1.9.

First, suppose the U.S. were in a goods only treaty with Japan in 2008. This corresponds

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	0.02	0.19	-0.25	-0.07	0.19	0.26	0.27	0.03
Austria	0.13	0.20	-0.11	-0.05	0.19	0.24	0.25	0.03
Canada	0.23	0.14	0.12	0.03	0.09	0.11	0.11	0.01
Czech	0.17	0.20	-0.10	-0.07	0.19	0.25	0.27	0.05
Denmark	0.19	0.22	-0.03	0.00	0.18	0.21	0.22	0.01
Finland	0.22	0.21	0.01	0.00	0.17	0.22	0.21	0.01
France	0.16	0.18	-0.09	-0.06	0.17	0.23	0.25	0.03
Germany	0.16	0.18	-0.08	-0.06	0.18	0.23	0.24	0.03
Greece	0.16	0.17	-0.08	-0.07	0.20	0.24	0.24	0.03
Hungary	0.38	0.31	0.34	0.17	0.16	0.14	0.14	-0.01
Ireland	0.28	0.31	0.11	0.15	0.16	0.17	0.16	-0.00
Italy	-0.10	0.17	-0.46	-0.20	0.25	0.35	0.37	0.05
Japan	0.17	0.04	-0.03	-0.16	0.13	0.16	0.20	0.05
Korea	0.06	0.19	-0.24	-0.12	0.17	0.27	0.31	0.07
Norway	0.14	0.22	-0.10	-0.02	0.20	0.24	0.25	0.03
Poland	-0.10	0.14	-0.45	-0.21	0.22	0.32	0.35	0.07
Portugal	0.56	0.19	0.54	0.18	0.08	0.03	0.01	-0.03
Slovak	0.32	0.25	0.12	0.06	0.17	0.19	0.19	0.02
Slovenia	0.14	0.22	-0.12	-0.04	0.20	0.25	0.26	0.03
Spain	0.49	0.21	0.43	0.15	0.09	0.07	0.06	-0.01
Sweden	0.09	0.19	-0.17	-0.01	0.19	0.24	0.26	0.01
U.K.	0.27	0.23	0.09	0.04	0.17	0.18	0.18	0.01
U.S.	0.22	0.20	-0.05	0.09	0.10	0.11	0.11	0.01

Note: Numbers show changes in percentage points.

Table 1.7. Effect of U.S. - Japan Treaty, Services Only

to setting ta_M between U.S. and Japan to 1, which produces a counterfactual $\hat{d}_{nij}$ matrix. Computing the outcome reveals that this treaty will would boost $\pi_{US,JP,M}$ by 131% and $\pi_{JP,US,M}$ by 181%. Meanwhile, the average share of U.S. manufacturing import from other countries would drop by over 3%. Inevitably, the treaty would enhance trade in manufacturing, but what is interesting is that it would cause 18% in Japan's services import and a 15% decrease in services export. Apparently, Japan would increasingly specialize in manufacturing over services. For the U.S., average services import share would drop by 2% and services export would increase by 2%, i.e. the U.S. would specialize more in services. The

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	0.63	0.74	-0.08	0.02	0.62	0.71	0.71	0.04
Austria	0.73	0.83	-0.09	0.01	0.66	0.79	0.82	0.07
Canada	-0.66	0.90	-1.07	0.48	0.41	0.46	0.41	-0.03
Czech	0.89	0.87	-0.00	-0.01	0.65	0.83	0.89	0.14
Denmark	0.72	0.84	-0.10	0.02	0.67	0.80	0.82	0.06
Finland	0.71	0.79	-0.14	-0.06	0.68	0.81	0.85	0.07
France	0.76	0.78	-0.10	-0.08	0.63	0.83	0.86	0.08
Germany	0.74	0.83	-0.11	-0.01	0.65	0.82	0.84	0.08
Greece	0.84	0.77	0.05	-0.01	0.68	0.77	0.79	0.06
Hungary	0.75	0.86	-0.09	0.02	0.65	0.80	0.84	0.10
Ireland	0.60	0.89	-0.18	0.11	0.70	0.78	0.79	0.03
Italy	0.83	0.83	0.22	0.22	0.63	0.78	0.81	0.07
Japan	3.60	2.21	1.03	-0.33	1.46	2.33	2.53	0.41
Korea	1.37	1.30	-0.04	-0.11	0.98	1.30	1.41	0.22
Norway	0.09	0.95	0.09	0.14	0.70	0.79	0.81	0.06
Poland	0.82	0.81	-0.01	-0.01	0.66	0.79	0.83	0.10
Portugal	0.88	0.76	0.11	-0.01	0.63	0.75	0.77	0.06
Slovak	0.73	0.82	-0.16	-0.07	0.66	0.84	0.89	0.15
Slovenia	0.75	0.80	-0.04	0.01	0.65	0.76	0.79	0.08
Spain	0.78	0.77	-0.05	-0.06	0.64	0.79	0.83	0.08
Sweden	0.78	0.83	-0.04	0.01	0.68	0.79	0.82	0.06
U.K.	0.68	0.80	-0.12	-0.01	0.67	0.79	0.81	0.06
U.S.	0.18	0.70	-0.47	0.04	-0.02	0.58	0.66	0.21

Note: Numbers show changes in percentage points.

Table 1.8. Effect of U.S. - Japan Treaty, Manufacturing and Services

spillover effect on trade shares between other countries are negligible. In addition, the goods treaty would also withdraw labor from the services sector to the manufacturing sector in both countries. In terms of welfare, U.S. buyers would face a 0.31% drop in manufacturing price, while Japan's manufacturing price increase by 1.38% due to the 2.44% rise in nominal wage. Nevertheless, real wage increases slightly in both countries. The effect on other countries are insignificant in most cases.

If a services treaty were in place between U.S. and Japan in 2008, the trade share between the two would increase by over 50%. Japan's average services import from other countries

Country	Output		Employment		Price Level		Wage	
	M	S	M	S	M	S	Nominal	Real
Australia	-7.32	-0.72	-0.59	0.80	-5.02	-1.90	-1.50	0.99
Austria	-0.00	-0.15	0.13	-0.01	-1.77	-0.47	-0.13	0.62
Canada	-3.45	0.12	-2.51	1.09	-2.33	-1.13	-0.96	0.40
Czech	-0.31	-0.03	-0.15	0.12	-1.53	-0.50	-0.15	0.63
Denmark	1.35	-0.52	1.42	-0.45	-1.93	-0.57	-0.07	0.72
Finland	1.07	-0.55	1.13	-0.49	-1.76	-0.55	-0.06	0.70
France	-0.53	-0.46	-0.05	0.01	-1.42	-0.66	-0.47	0.34
Germany	-0.06	-0.53	0.31	-0.17	-1.56	-0.59	-0.36	0.47
Greece	-5.32	0.36	-4.76	0.96	-2.20	-0.88	-0.59	0.57
Hungary	2.20	0.71	1.07	-0.40	-2.50	0.24	1.11	1.65
Ireland	-0.04	0.27	-0.27	0.04	-2.16	-0.46	0.23	0.97
Italy	-0.56	-0.43	-0.08	0.06	-1.39	-0.68	-0.48	0.36
Japan	4.94	2.20	2.04	-0.63	0.22	2.32	2.84	0.97
Korea	11.65	2.46	5.37	-3.30	-4.84	2.57	5.95	5.30
Norway	-1.92	-0.42	-1.39	0.11	-1.66	-0.79	-0.52	0.40
Poland	-0.74	-0.03	-0.47	0.25	-1.71	-0.63	-0.28	0.65
Portugal	-2.14	-0.06	-1.66	0.43	-2.10	-0.80	-0.49	0.59
Slovak	0.59	0.74	-0.13	0.12	-2.09	0.06	0.72	1.46
Slovenia	0.35	0.37	-0.03	0.01	-2.12	-0.20	0.38	1.11
Spain	-1.45	-0.12	-1.08	0.25	-1.92	-0.73	-0.38	0.59
Sweden	1.24	-0.29	1.17	-0.36	-1.96	-0.44	0.07	0.83
U.K.	1.22	-0.06	1.04	-0.25	-2.27	-0.33	0.19	0.85
U.S.	-1.99	-0.18	-1.51	0.30	-2.95	-0.85	-0.48	0.77

Note: Numbers show changes in percentage points.

Table 1.9. Effect of Worldwide Treaty, Manufacturing and Services

would drop by around 3% and U.S. would drop by 1%. However, services treaty would not significantly alter manufacturing trade shares as the goods treaty would do previously. Japan would still be specializing more into manufacturing but the production in the U.S. would be almost unchanged. The welfare effect of services treaty is also negligible to both countries. In short, the benefit of a services only treaty is not as obvious as a goods treaty.

The effect of a comprehensive treaty appears to be the combination of the previous two cases. Real wage increase in both countries is not much different from the goods only case. The services clause does not seem to contribute much additional welfare gains. Manufacturing trade shares between the two countries increases much more than services trade, $\pi_{US,JP,M}$ up by 134%, $\pi_{JP,US,M}$ by 177%, while $\pi_{US,JP,S}$ up by 86% and $\pi_{JP,US,S}$ only by 33%.

Lastly, suppose a comprehensive treaty exists between every country pairs in the sample. These treaties would induce a worldwide decrease in price levels. While nominal wage decreases in many countries, real wage increases in all countries. Korea would see the largest gains of 5.3%, followed by Hungary at 1.65%. Most countries' gains from trade is within 1%. Furthermore, richer countries trend to specialize more in services as employment migrates from manufacturing to services. In terms of trade share, new treaties would double trade shares of non-EU countries. Since most EU members were already covered by existing treaties, their trade shares would generally decrease under the competition of new treaties.

1.4.2.2 General Trade Frictions

Since other changes related to trade frictions will induce changes to d_{nij} like regional trade agreements, I will consider general reduction of d_{nij} in this section. Like before, I will conduct experiments for goods only reduction, services only reduction, and comprehensive reductions. Results are summarized in tables 1.10 through 1.12.

First, consider a 5% reduction in manufacturing frictions worldwide. Price for manufactured goods would drop by over 6% on average. Services price would also decrease by 1% due to the input-output linkage. Nominal wage does not change much but real wage would increase by 2.7% on average worldwide. Like before, richer countries would be more specialized in services as labor shifts from manufacturing to services.

Repeating the exercise for a 5% reduction in services frictions worldwide would decrease global services price by 7%. Since the share of services intermediates in manufacturing output is higher than manufacturing intermediates in services output, manufacturing price would also drop by approximately 2%. The two combined results in a 7% increase in real wage. Labor shifts from manufacturing to services in most countries in this case. Clearly, the

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	-0.74	-0.19	-0.50	0.04	-6.58	-0.92	-0.23	1.81
Austria	0.22	0.60	-0.19	0.19	-6.85	-0.75	0.41	2.59
Canada	0.78	0.13	0.40	-0.25	-6.71	-0.81	0.38	2.41
Czech	4.35	1.27	2.05	-0.96	-7.09	0.09	2.25	4.41
Denmark	-0.58	0.68	-1.08	0.17	-6.83	-0.71	0.51	2.31
Finland	0.66	0.76	-0.19	0.09	-6.92	-0.73	0.86	2.76
France	1.14	0.34	0.65	-0.14	-6.71	-0.49	0.84	2.36
Germany	0.58	0.01	0.27	-0.29	-6.76	-0.51	0.30	2.50
Greece	-1.54	0.26	-1.56	0.24	-6.55	-1.00	0.02	2.35
Hungary	3.44	0.91	1.81	-0.64	-6.88	-0.25	1.56	2.76
Ireland	-2.69	1.06	-2.86	0.89	-6.74	-0.94	0.18	2.12
Italy	0.58	0.62	-0.02	0.02	-6.82	-0.71	0.60	2.78
Japan	0.38	0.30	0.13	-0.05	-6.59	-0.76	0.25	2.28
Korea	2.88	1.93	0.47	-0.47	-6.84	-0.02	2.40	4.26
Norway	-0.40	0.66	-0.81	0.24	-9.66	-0.91	0.24	2.54
Poland	0.50	1.20	-0.47	0.05	-6.86	-0.84	0.98	3.67
Portugal	1.08	0.66	0.31	-0.11	-6.90	-0.60	0.76	2.84
Slovak	2.07	1.12	0.51	-0.43	-6.89	-0.34	1.55	4.41
Slovenia	2.06	1.03	0.74	-0.27	-6.94	-0.52	1.31	3.67
Spain	1.09	0.83	0.10	-0.15	-6.87	-0.58	0.98	2.91
Sweden	0.24	0.64	-0.21	0.18	-6.86	-0.85	0.46	2.65
U.K.	-0.49	0.53	-0.78	0.24	-6.83	-0.83	0.29	2.22
U.S.	-0.37	0.05	-0.35	0.06	-6.69	-0.87	-0.01	2.02

Note: Numbers show changes in percentage points.

Table 1.10. Effect of 5% Manufacturing Frictions Reduction

potential gains entailing services trade liberaliztion is huge, the problem is that conventional trade agreements may not be the most effective tool to lift services trade barriers.

If frictions in both sectors decrease, for instance 2.5% for manufacturing and 5% for services in the case presented, prices would drop by 5% and 7% respectively and real wage would increase by more than 8% worldwide.

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	0.65	0.21	0.36	-0.07	-2.13	-6.71	0.28	6.40
Austria	0.21	0.73	-0.32	0.18	-1.88	-7.10	0.54	6.78
Canada	-0.77	0.45	-0.86	0.36	-2.08	-7.10	0.09	6.51
Czech	-0.74	2.66	-2.32	1.01	-1.76	-7.72	1.62	7.80
Denmark	-1.23	1.92	-2.53	0.57	-1.83	-7.16	1.34	8.01
Finland	0.29	1.00	-0.60	0.09	-1.91	-7.08	0.90	7.45
France	2.44	0.85	1.27	-0.29	-2.04	-6.63	1.14	7.18
Germany	0.47	0.52	-0.26	-0.21	-1.89	-6.85	0.73	6.58
Greece	0.13	-0.22	0.21	-0.13	-2.03	-6.73	-0.07	5.68
Hungary	0.31	0.76	-0.30	0.14	-1.85	-7.05	0.61	6.41
Ireland	3.39	1.64	1.41	-0.29	-2.21	-7.01	1.94	8.66
Italy	1.15	1.00	0.10	-0.04	-2.00	-6.84	1.04	7.12
Japan	0.05	0.03	-0.06	-0.08	-1.76	-6.61	0.11	5.99
Korea	-0.20	0.25	-0.41	0.04	-1.67	-7.06	0.20	6.18
Norway	-0.06	1.49	-1.06	0.46	-1.82	-7.26	1.01	7.45
Poland	0.79	0.80	-0.21	-0.20	-1.91	-6.84	1.00	6.54
Portugal	0.02	0.66	-0.57	0.06	-1.81	-7.14	0.60	6.85
Slovak	-0.28	0.81	-0.80	0.27	-1.83	-7.24	0.52	5.81
Slovenia	-0.56	1.21	-1.34	0.41	-1.85	-7.37	0.79	6.86
Spain	0.17	0.76	-0.67	-0.08	-1.84	-6.98	0.85	7.16
Sweden	1.65	1.07	0.51	-0.06	-2.01	-6.92	1.13	7.38
U.K.	-0.09	1.43	-1.20	0.30	-1.92	-7.10	1.12	7.74
U.S.	0.71	0.34	-0.39	0.02	-2.10	-7.01	0.31	6.68

Note: Numbers show changes in percentage points.

Table 1.11. Effect of 5% Services Frictions Reduction

1.4.2.3 State of Technology

Another way to alter the landscape of international trade is through technological advancements. In this section, I will present four experiments involving changes of technology including a major breakthrough in M of one country, in S of the same country, simultaneous breakthrough in both sectors, and breakthrough in M in two competing countries. Results are summarized in tables 1.13 through 1.16.

First, consider $\hat{\tilde{T}}_{US,M} = 1.1\tilde{T}_{US,M}$, i.e. an 10% increase in the U.S. manufacturing tech-

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	0.20	0.02	0.13	-0.05	-5.43	-7.22	0.07	7.34
Austria	0.08	0.83	-0.52	0.21	-5.38	-7.57	0.61	8.14
Canada	-0.74	0.51	-0.71	0.27	-5.40	-7.49	0.24	7.75
Czech	1.19	3.08	-1.31	0.51	-5.39	-7.84	2.55	10.08
Denmark	-1.59	2.11	-2.96	0.69	-5.34	-7.65	1.14	9.22
Finland	0.46	1.24	-0.69	0.07	-5.44	-7.56	1.16	8.89
France	2.92	0.88	1.72	-0.29	-5.47	-7.03	1.18	8.40
Germany	0.72	0.44	0.06	-0.21	-5.36	-7.27	0.66	7.85
Greece	-0.72	-0.21	-0.46	0.04	-5.39	-7.36	-0.25	6.88
Hungary	1.83	1.05	0.60	-0.16	-5.36	-7.31	1.21	8.35
Ireland	1.82	2.00	-0.06	0.12	-5.65	-7.57	1.88	9.78
Italy	1.30	1.15	0.14	-0.00	-5.49	-7.33	1.15	8.56
Japan	0.12	-0.00	0.10	-0.02	-5.16	-7.16	0.01	7.15
Korea	1.08	1.05	-0.08	-0.12	-5.18	-7.25	1.17	8.35
Norway	-0.40	1.65	-1.45	0.58	-5.40	-7.83	1.05	8.77
Poland	1.00	1.16	-0.26	-0.09	-5.44	-7.42	1.26	8.41
Portugal	0.41	0.84	-0.37	0.04	-5.35	-7.57	0.79	8.32
Slovak	0.54	1.18	-0.75	0.06	-5.35	-7.57	1.12	8.06
Slovenia	0.30	1.57	-0.95	0.29	-5.40	-7.76	1.27	8.75
Spain	0.64	1.04	-0.47	-0.07	-5.37	-7.43	1.12	8.66
Sweden	1.54	4.21	0.31	-0.01	-5.51	-7.44	1.23	8.76
U.K.	-0.54	1.51	-1.65	0.37	-5.41	-7.61	1.13	8.91
U.S.	0.36	0.28	0.06	-0.01	-5.42	-7.42	0.29	7.75

Note: Numbers show changes in percentage points.

Table 1.12. Effect of 2.5% Manufacturing and 5% Services Frictions Reduction

nology. This would lower the U.S. manufacturing price by over 5%. Canada, being the closet trade partner of the U.S. also enjoy similar price reduction. The price reduction would also spillover to most other countries in the sample. Due to the rise in nominal wage, services price would rise in both U.S. and Canada. Nevertheless, real wage would still increase by 3.77% in the U.S. The increased demand for cheaper U.S. manufactured goods would boost output by almost 16% and employment by 9%. Canada on the other hand would endure higher competition from the cheaper U.S. alternative, resulting in a 19% reduction of output and 21% massive layoff of manufacturing employed labor. Despite strong structural change

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	-7.11	0.05	-6.37	0.85	-1.64	-0.82	-0.79	0.18
Austria	-1.94	0.48	-1.72	0.71	-0.33	-0.19	-0.22	-0.00
Canada	-19.35	12.10	-21.17	9.57	-5.02	1.98	2.30	1.75
Czech	-1.81	0.35	-1.46	0.71	-0.31	-0.31	-0.35	-0.05
Denmark	-2.77	0.65	-2.79	0.63	-0.29	0.03	0.02	0.03
Finland	-2.35	0.57	-2.14	0.79	-0.32	-0.15	-0.21	-0.03
France	-2.52	0.24	-2.42	0.35	-0.23	-0.07	-0.10	0.00
Germany	-2.22	0.47	-2.03	0.66	-0.26	-0.12	-0.19	-0.03
Greece	-2.12	0.74	-2.42	0.44	-0.11	0.25	0.30	0.14
Hungary	-2.43	0.89	-2.50	0.82	-0.39	0.00	0.07	0.17
Ireland	-3.24	1.15	-3.37	1.01	-0.26	0.16	0.13	0.04
Italy	-1.67	0.16	-1.36	0.48	-0.33	-0.28	-0.32	-0.02
Japan	-1.97	-0.48	-1.33	0.16	-0.51	-0.60	-0.65	-0.07
Korea	-2.28	0.00	-1.54	0.76	-0.61	-0.63	-0.75	-0.13
Norway	-2.47	0.55	-2.47	0.55	-0.23	0.00	0.00	0.04
Poland	-1.90	0.07	-1.65	0.33	-0.33	-0.25	-0.25	0.01
Portugal	-2.27	0.40	-2.23	0.45	-0.30	-0.07	-0.04	0.07
Slovak	-2.19	0.59	-1.92	0.87	-0.40	-0.28	-0.27	0.03
Slovenia	-1.86	0.38	-1.75	0.49	-0.37	-0.15	-0.11	0.09
Spain	-2.71	0.58	-2.76	0.53	-0.26	0.02	0.05	0.09
Sweden	-2.68	0.57	-2.58	0.68	-0.31	-0.07	-0.10	0.01
U.K.	-3.56	0.84	-3.71	0.68	-0.35	0.12	0.16	0.12
U.S.	15.84	4.60	8.67	-1.85	-5.55	4.87	6.56	3.77

Note: Numbers show changes in percentage points.

Table 1.13. Effect of 10% U.S. Manufacturing Efficiency Improvement

in output and employment, Real welfare would still increase by 1.75% in Canada. Other than Canada, countries with higher services comparative advantage would enjoy marginal gains, while countries with manufacturing comparative advantage slightly suffer.

Second, if the 10% technological breakthrough were in services, services price would decline in the U.S. and other countries. Services production and employment would increase in the U.S. while the Canadian services sector suffer the most. Note that the gains of the breakthrough compounded by trade would be 13.8% for the U.S., 3.7 timed higher than the gains from a manufacturing breakthrough of equal size. But due to the lower services trade

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	4.17	-0.37	3.91	-0.62	0.59	0.21	0.25	-0.03
Austria	1.49	-0.54	1.60	-0.43	0.00	-0.14	-0.10	0.00
Canada	21.59	-10.87	22.61	-10.39	2.19	-1.49	-0.53	0.22
Czech	1.25	-0.38	1.25	-0.38	0.02	-0.03	0.00	0.01
Denmark	1.88	-0.90	2.05	-0.73	0.00	-0.24	-0.16	0.03
Finland	1.74	-0.84	1.82	-0.76	-0.01	-0.17	-0.07	0.06
France	1.63	-0.47	1.75	-0.35	-0.02	-0.16	-0.11	0.01
Germany	1.34	-0.78	1.35	-0.77	-0.00	-0.10	-0.01	0.06
Greece	0.99	-0.64	1.32	-0.32	-0.11	-0.32	-0.32	-0.06
Hungary	1.68	-0.68	1.85	-0.52	0.05	-0.16	-0.16	-0.06
Ireland	2.49	-0.88	2.79	-0.58	-0.08	-0.40	-0.29	0.04
Italy	1.22	-0.36	1.29	-0.29	-0.01	-0.10	-0.06	0.01
Japan	1.25	0.36	0.55	-0.34	0.49	0.63	0.70	0.10
Korea	1.74	-0.36	1.25	-0.83	0.34	0.33	0.47	0.14
Norway	1.42	-0.76	1.58	-0.60	-0.03	-0.19	-0.15	0.00
Poland	0.84	-0.30	0.71	-0.43	0.08	0.08	0.12	0.04
Portugal	1.20	-0.41	1.25	-0.35	0.04	-0.06	-0.05	-0.01
Slovak	1.19	-0.53	1.04	-0.68	0.09	0.10	0.14	0.05
Slovenia	1.13	-0.42	1.19	-0.37	0.03	-0.06	-0.05	-0.02
Spain	1.35	-0.61	1.40	-0.57	0.04	-0.07	-0.05	0.00
Sweden	2.04	-0.71	2.19	-0.56	-0.01	-0.21	-0.15	0.02
U.K.	2.68	-0.76	3.01	-0.45	-0.01	-0.33	-0.31	-0.03
U.S.	3.34	11.31	-6.27	0.95	2.47	-4.48	10.26	13.80

Note: Numbers show changes in percentage points.

Table 1.14. Effect of 10% U.S. Services Efficiency Improvement

intensity, other countries benefit much less, for instance Canada's gains would only be 0.22%.

Third, consider a 5% increase in both sectors. Real wage in the U.S. would increase by 8.81%. Nominal wage in other countries except Canada declines. Production of both sectors would shrink in other countries facing competition from the U.S..

Last but not least, Consider a 10% increase in the manufacturing technology of the U.S. and a 5% increase in that of Germany. In this case, the European countries can benefit more from the Germany breakthrough. Output of the U.S. and Germany manufacturing sector would increase by 15% and 11% respectively while the production in the rest of the

	Output		Employment		Price Level		Wage	
Country	M	S	M	S	M	S	Nominal	Real
Australia	-1.48	-0.34	-0.99	0.15	-0.63	-0.50	-0.49	0.02
Austria	-0.46	-0.15	-0.25	0.05	-0.20	-0.20	-0.20	-0.00
Canada	-0.34	0.62	-0.73	0.23	-1.54	0.02	0.39	0.67
Czech	-0.53	-0.18	-0.29	0.04	-0.19	-0.22	-0.23	-0.02
Denmark	-0.56	-0.13	-0.38	0.04	-0.20	-0.18	-0.18	0.00
Finland	-0.49	-0.16	-0.26	0.07	-0.22	-0.22	-0.23	-0.01
France	-0.69	-0.22	-0.52	-0.05	-0.17	-0.16	-0.16	0.00
Germany	-0.60	-0.22	-0.42	-0.03	-0.18	-0.18	-0.18	-0.00
Greece	-0.58	-0.10	-0.44	0.03	-0.18	-0.14	-0.13	0.01
Hungary	-0.44	-0.05	-0.22	0.16	-0.22	-0.21	-0.21	-0.00
Ireland	-0.55	0.02	-0.37	0.20	-0.22	-0.18	-0.18	0.00
Italy	-0.67	-0.23	-0.55	-0.11	-0.14	-0.12	-0.12	0.00
Japan	-0.46	-0.37	-0.05	0.03	-0.30	-0.39	-0.41	-0.04
Korea	-0.48	-0.29	-0.05	0.14	-0.30	-0.39	-0.43	-0.06
Norway	-0.70	-0.20	-0.55	-0.05	-0.19	-0.16	-0.15	0.00
Poland	-0.59	-0.21	-0.41	-0.03	-0.19	-0.18	-0.18	-0.00
Portugal	-0.19	-0.14	0.22	0.27	-0.31	-0.39	-0.41	-0.04
Slovak	-0.47	-0.11	-0.22	0.12	-0.22	-0.23	-0.24	-0.02
Slovenia	-0.46	-0.12	-0.29	0.04	-0.19	-0.17	-0.17	0.00
Spain	-0.32	-0.12	0.02	0.23	-0.29	-0.33	-0.35	-0.03
Sweden	-0.63	-0.19	-0.45	-0.01	-0.20	-0.18	-0.18	0.00
U.K.	-0.72	-0.13	-0.57	0.01	-0.22	-0.16	-0.14	0.02
U.S.	9.76	7.82	1.29	-0.49	-1.69	-0.10	8.36	8.81

Note: Numbers show changes in percentage points.

Table 1.15. Effect of 5% U.S. Manufacturing and Services Efficiency Improvement

world declines. Labor shifts with changes in production. Most countries benefit from the breakthrough. Real wage would rise in most countries except Japan and Korea which are the major manufacturing competitors of U.S. and Germany and are too remote for the spillover benefits.

Country	Output M	Output S	Employment M	Employment S	Price Level M	Price Level S	Wage Nominal	Wage Real
Australia	-7.90	-0.06	-6.96	0.95	-1.92	-1.05	-1.01	0.19
Austria	-4.91	1.43	-4.72	1.64	-1.48	-0.31	-0.20	0.36
Canada	-19.91	11.94	-21.49	9.73	-5.27	1.71	2.00	1.72
Czech	-5.39	2.74	-5.62	2.49	-1.62	-0.07	0.23	0.76
Denmark	-7.59	3.78	-8.84	2.39	-1.97	0.98	1.36	0.89
Finland	-4.43	0.89	-3.84	1.51	-0.88	-0.51	-0.61	-0.03
France	-6.93	1.50	-7.21	1.19	-1.21	0.21	0.30	0.40
Germany	11.07	0.48	6.96	-3.23	-2.45	2.74	3.83	2.47
Greece	-4.41	1.24	-4.82	0.80	-0.49	0.31	0.43	0.31
Hungary	-4.80	1.94	-5.03	1.69	-1.35	-0.07	0.24	0.64
Ireland	-7.21	2.56	-7.62	2.10	-0.74	0.43	0.45	0.21
Italy	-3.81	0.22	-3.10	0.97	-0.96	-0.70	-0.73	0.02
Japan	-2.66	-0.98	-1.42	0.28	-0.96	-1.19	-1.26	-0.13
Korea	-3.20	-0.29	-1.98	0.96	-1.00	-1.90	-1.24	-0.19
Norway	-5.42	1.08	-5.39	1.12	-0.83	-0.09	-0.03	0.20
Poland	-4.93	1.07	-4.57	1.45	-1.36	-0.54	-0.37	0.39
Portugal	-4.24	0.62	-3.94	0.93	-0.90	-0.38	-0.31	0.17
Slovak	-4.66	1.39	-4.10	1.98	-1.27	-0.69	-0.58	0.28
Slovenia	-3.87	0.88	-3.60	1.16	-1.21	-0.44	-0.28	0.36
Spain	-4.74	0.73	-4.53	0.94	-0.77	-0.27	-0.21	0.15
Sweden	-5.40	1.18	-5.14	1.46	-1.06	-0.28	-0.27	0.17
U.K.	-8.09	2.38	-8.81	1.58	-1.37	0.52	0.78	0.59
U.S.	14.99	4.47	8.17	-1.72	-5.78	4.59	6.30	3.76

Note: Numbers show changes in percentage points.

Table 1.16. Effect of 10% U.S. and 5% Germany Manufacturing Efficiency Improvement

1.5 Conclusion

This chapter brings the seminal Eaton and Kortum (2002) model to the international trade of services and provided additional evidence for services gravity. Estimating the model produced plausible estimates of services productivities across countries. Outcomes of the counterfactual experiments also reveal high potential gains in services trade. For equal amount of reduction in trade frictions or technological progress, services can bring up to 3 to 4 times higher gains from trade than manufacturing. In addition, results also indicate that services trade reacts less elastically to trade agreements compared to goods, distance is less obstructive to services trade, and common language does not promote services trade. This snapshot view can serve as a good benchmark for future studies. In the next chapter, I will continue using the current framework to present a more granular view of how underlying drivers of services trade, namely relative productivity differences and trade frictions, change over time. Particularly, I will focus on the evolution of services comparative advantage from 1995 to 2011 in 40 countries with different income levels.

Chapter 2

The Evolution of Services Comparative Advantage

2.1 Introduction

It has been demonstrated in the previous chapter that the extended Eaton and Kortum (2002) model fits the bilateral services trade well. Estimation of the model yielded reasonable sector level productivities for both manufacturing and services in 23 OECD countries. The series of counterfactual experiments also confirmed significant potential gains from services trade. With identical amount of reduction in trade frictions or progress in productivity, the gains from services trade would typically be 3 to 4 times larger than the gains from goods trade. This chapter aims to further our understanding of services trade by extending the previous analysis in three directions. First and foremost, it tracks the growth of productivities and evolution of comparative advantages over 17 years from 1995 to 2011. Second, the sample expands to 40 major world economies including non-OECD countries like Brazil, China, India, etc., allowing for a more comprehensive view of the landscape of trade and comparative advantage over time. Last but not least, the data covers 35 broad industries with 14 in manufacturing and 17 in services that constitute the entire economic spectrum. The industry level trade data allows us to look into the services sector and measure the distribution of productivities within the sector. Moreover, since trade is allowed in all industries, our model can capture the gains from trade that were previously unaccounted for in the existing literature.

The main results of this chapter suggest that comparative advantage was weakened during the period in all countries and all sectors including services. In fact, the average rate of relative convergence in the services sector was 75% faster than that of the manufacturing sector. Non-OECD countries experienced 35% stronger relative convergence than OECD countries. Even though comparative advantage became weaker, Non-OECD countries still hold their persistent advantage in manufacturing industries compared to OECD countries. In addition, the estimated productivities confirmed that initially comparatively disadvantageous industries grew systematically faster. Such trend persisted in all sub-intervals of the period. These findings are in line with the conclusions of Levchenko and Zhang (2011), who studied the manufacturing industries from 1960 to 2000. Furthermore, evidence in support of random diffusion theory as a potential mechanism behind the convergence growth was also found in our estimates. In this mechanism proposed by Alvarez et al. (2013), productivity progresses as producers across countries and industries randomly meet, exchange ideas and improve efficiencies. The magnitude of convergence is determined by the speed of diffusion, which we estimated to be 3.6% across industries within each country and 6.0% across countries for every industry. Finally, through a counterfactual experiment where the level of comparative advantage in 1995 were preserved in 2011, we found that weakened comparative advantage eliminated 3.9% of gains from trade for the median country. Countries like China missed as much as 19.6% while others like Indonesia might suffer a loss of as much as 4.3% in the counterfactual world. The relative convergence also removed 25% of total trade volume by suppressing the incentives to trade.

Because of its central role in the measurement of gains from trade, estimating and tracking comparative advantage as long been a key focus of trade studies. While absolute technological progress in a single sector world leads to unambiguous gains, the welfare consequence of technological improvements in a multi-sector world with trade is not as straight forward. In typical Ricardian settings, greater relative technological differences create more incentives to trade and lead to larger gains from trade. If technology grows such that countries converge to each other in terms of relative technological difference across sectors, it is possible for welfare to decrease.[1] Therefore, accurate accounting for the welfare gains not only depends on the absolute growth of productivities, but also how relative productivities evolve over time across sectors.

Existing studies on this topic were limited to the goods producing, mainly manufacturing, industries mostly because bilateral trade data were not available for most services. As a result, 70% of the world economy and 1/4 of total trade volume were left out of the analysis or taken as an outside sector whose main function was to complete the equilibrium. This can cause bias in the existing welfare measurements and the projected comparative advantage are also conditional and incomplete. This chapter utilizes industry-level services trade data to re-assess some of the existing results. As the model allows trade in all industries, the evolution of comparative advantage is no longer limited to the manufacturing sector. Relative productivity difference between services and other sectors can create additional incentives to trade that offer additional welfare potential.

This chapter use the widely popular methodology developed by Eaton and Kortum (2002) to estimate industrial productivities. Chapter 1 has already demonstrated that it is able to produce reasonable fit to trade in services. Compared to the traditional neoclassical TFP estimation which heavily depends on country-specific variable, the estimates obtained using

[1]See Jones (1979), Krugman (1979) and Samuelson (2004) among others for related discussion on technological change in Ricardian models.

trade flows are typically more robust to cross-sectional comparisons. As the estimation relied on bilateral trade flows, it can be easily extended to include more countries and finer industry definitions for which data is available. By incorporating input and output structure into the model, we are able to control for the productivity spill-over embedded in the intermediate production inputs and further reduce bias in the productivity estimates.

Although the literature on productivity estimation using trade data is abundant, most focus on just the manufacturing sectors. Caliendo and Parro (2009) applied a multi-sector Eaton-Kortum model for manufacturing industries to analyze the impact of NAFTA. Waugh (2010) estimated productivity with a single sector model emphasizing on asymmetries in trade frictions. Shikher (2012) estimated sectoral productivity for OECD countries. Costinot et al. (2012) also conducted similar exercise. Besides the static studies, many others analyzed the impact of changes in productivity. For instance, Hausmann and Klinger (2007) discussed changes in revealed comparative advantage and its relation to export patterns Hsieh and Ossa (2011) examined the productivity growth in China from 1993 to 2005. Finicelli et al. (2009) estimated manufacturing FTP from 1985 to 2002 using one sector Eaton-Kortum model. Levchenko and Zhang (2011) estimated productivity for 19 manufacturing industries in 72 countries from 1960 to 2000 and analyzed the evolution of the implied comparative advantage. Bernard and Jones (1996b) studies technological convergence but their estimation was based on production data.[2]

This chapter is the first to extend the analysis to include services – the missing piece in trade and comparative advantage. The methodology of this chapter closely follows that of Levchenko and Zhang (2011). As we shared the same framework, it is easy to compare and contrast our results with theirs. Since this chapter covers different time period and countries and includes trade in all industries, shared framework also enables us to validate and extend

[2] Hanson et al. (2015) identified additional regularities in changes of productivity such as hyper-specialization and high turnover rate in top export industries., and discussed possible dynamic models for comparative advantage.

their conclusions and demonstrate the significance of services as the missing piece in trade literature.

This chapter is also among the first to test the random diffusion theory for technological convergence. Lucas (2009) started the idea where producers randomly running into each other to exchange ideas can lead to technology diffusion. Alvarez et al. (2013) brought this idea into trade and generated convergence across countries. Perla et al. (2012) applied the same mechanism in an otherwise standard static Melitz model and characterized dynamic equilibrium diffusion within a sector along balanced growth paths.

The rest of this chapter is organized as follows. Section 2 reiterates the multi-sector Eaton-Kortum model we used in chapter 1. Section 3 details the steps to obtain productivity estimates. Section 4 presents pattern in the estimated productivities and discusses the evolution of comparative advantage and its welfare implication. Section 5 concludes.

2.2 The Model

Except for a few notational changes, the model in this chapter is identical to the multi-sectoral Eaton and Kortum model with input and output linkage presented in section 1.2. There are I countries, indexed by i or n, in a fully competitive world. Production in each country is divided into J industries indexed by j or l. Output of all industries can be traded. A subscript t will be attached to quantities that may vary through time. Each country is endowed with L_{it} units of labor in period t. They are perfectly mobile across industries but immobile across countries. There is no inter-temporal savings and labor is the only factor of production.

Denote the gross absorption and production of industry j in country i and time period t by X_{ijt} and Y_{ijt}. Industry deficits can be computed by $D_{ijt} = X_{ijt} - Y_{ijt}$. Country i's total trade deficit is simply the sum of industry deficits, i.e. $D_{it} = \sum_{j=1...J} D_{ijt}$. Denote by Y_{it}^F

and X_{it}^F the GDP and aggregate final spending in i. By definition,

$$X_{it}^F = Y_{it}^F + D_{it}.$$

As before, the model assumes a Cobb-Douglas production function that combines labor and intermediates input. In particular, let α_{ijt} be the share of total expenditures allocated to industry j in country i and time period t, β_{ijt} be labor's share of value-added in the gross output, and γ_{ijlt} be the share of intermediates from industry l in total intermediates used in the production of industry j. By assumption, $\sum_{j=1...J} \alpha_{ijt} = 1$ and $\sum_{l=1...J} \gamma_{ijlt} = 1$ for all i, j and t. It is thus possible to write the total absorption of industry j as the sum of final consumption and intermediates used in the production of all industries,

$$X_{ijt} = \alpha_{ijt} X_{it}^F + \sum_{l=1...J} \gamma_{iljt} \left(1 - \beta_{ilt}\right) Y_{ilt}. \tag{2.1}$$

GDP in this economy equals total labor income which is also equivalent to the total value added from all industries,

$$Y_{it}^F = w_{it} L_{it} = \sum_{j=1...J} \beta_{ijt} Y_{ijt}. \tag{2.2}$$

Also implied by the Cobb-Douglas production assumption is the following cost function

$$c_{ijt} = w_{it}^{\beta_{ijt}} \prod_{l=1...J} \left(P_{ilt}\right)^{(1-\beta_{ijt})\gamma_{ijlt}}, \tag{2.3}$$

where P_{ijt} is industry j's price index in country i and time period t.

Assume each industry is comprised of a continuum of varieties that can be indexed by their individual productivities z. Following the assumptions in Eaton and Kortum (2002),

z of each variety is an independent draw from a Frechet distribution

$$F_{ijt}(z) = \exp\left(-T_{ijt} z^{-\theta_j}\right),$$

where $T_{ijt} > 0$ represents the country-specific, time-varying overall efficiency of industry j in country i, and the inverse of $\theta_j > 1$ captures the global time-invariant dispersion of productivities across varieties in industry j. Average productivity of industry j in country i and period t is given by $T_{ijt}^{\frac{1}{\theta_j}}$.

As assumed, all varieties can be traded, but consuming foreign varieties will incur an additional iceberg cost denoted by $d_{nijt} \geq 1$, where subscript n is the destination where the variety is consumed, i is the origin where the variety is produced.[3] I make an additional assumption that $d_{iijt} = 1$ for all j, i and t. Therefore, the price of a variety with productivity z produced in n and consumed in i can be written as

$$p_{nijt}(z) = \frac{c_{ijt} d_{nijt}}{z}. \tag{2.4}$$

Perfect competition means that only the lowest-priced producer will survive in the market,

$$p_{njt}(z) = \min_{i=1..I} \{p_{nijt}(z)\}. \tag{2.5}$$

Demand over the varieties of industry j is assumed to be CES with elasticity σ_j,

$$Q_{njt} = \left[\int_z q_{njt}(z)^{\frac{\sigma_j - 1}{\sigma_j}} dF_{njt}\right]^{\frac{\sigma_j}{\sigma_j - 1}}.$$

[3] In the case of services varieties, n may not be the physical location where consumption takes place but the country where the consumer is from.

This leads to the price index

$$P_{njt} = \left[\int_z p_{njt}(z)^{1-\sigma_j} dF_{njt} \right]^{\frac{1}{1-\sigma_j}},$$

where $p_{njt}(z)$ is defined in equation 2.5. Following Eaton and Kortum (2002), the Frechet assumption allows us to re-write the above price index as

$$P_{njt} = \Gamma_j \left[\sum_{i=1}^{I} T_{ijt} \left(c_{ijt} d_{nijt} \right)^{-\theta_j} \right]^{-\frac{1}{\theta_j}}, \tag{2.6}$$

where $\Gamma_j = \Gamma \left(\frac{\theta_j + 1 - \sigma_j}{\theta_j} \right)^{\frac{1}{1-\sigma_j}}$ and $\theta_j > \sigma_j - 1$ must hold for it to exist.

Let π_{nijt} be the share of country n's expenditures on industry j's output produced in country i and X_{nijt} be the actual trade flow. Then π_{nijt} can be computed by

$$\pi_{nijt} = \frac{X_{nijt}}{X_{njt}} = \frac{T_{ijt} \left(c_{ijt} d_{nijt} \right)^{-\theta_j}}{\sum_{k=1...I} T_{kjt} \left(c_{kjt} d_{nkjt} \right)^{-\theta_j}}. \tag{2.7}$$

In addition, the trade flows must satisfy the market clearing condition

$$Y_{ijt} = \sum_{n=1...I} \pi_{nijt} X_{njt}. \tag{2.8}$$

Set the world GDP as the numeraire. Given the labor force L_{it} in each country, the demand parameters α_{ijt} and σ_j, the input-output parameters β_{ijt} and γ_{iljt}, the productivity distribution T_{ijt} and θ_j, total trade deficits D_{it}, and frictions d_{nijt}, the global equilibrium at period t is a set of wages w_{it}, prices p_{ijt} and trade flows X_{nijt} that jointly solve equations 2.1, 2.2, 2.6, 2.7 and 2.8. To track the evolution of comparative advantage of each industry, it remains to estimate the industry productivity parameter T_{ijt} for each i, j and t.

2.3 Model Estimation

This section modifies the method of Levchenko and Zhang (2011) to estimate the productivities T_{ijt}. Unlike chapter 1 where we need to fold the non-trading sector into the traded sectors, this section will explicitly estimate T_{ijt} for all i, j and t as trade can take place in any industry. Moreover, I will borrow existing estimates of sectoral dispersion θ_j in the literature to stream line the estimation process and focus on just T_{ijt}. Robustness of productivity estimates under alternative θ_j assumptions will be discussed at the end of the next chapter.

2.3.1 Estimating Industry Productivity Relative to the U.S.

The estimation equation can be derived in three steps. First, divide the trade shares defined in equation 2.7 by their domestic counterpart,

$$\frac{\pi_{nijt}}{\pi_{nnjt}} = \frac{X_{nijt}}{X_{nnjt}} = \frac{T_{ijt}\left(c_{ijt}d_{nijt}\right)^{-\theta_j}}{T_{njt}\left(c_{njt}\right)^{-\theta_j}}.$$

Next, take the natural log of the above,

$$\ln\left(\frac{X_{nijt}}{X_{nnjt}}\right) = \ln\left(T_{ijt}\left(c_{ijt}\right)^{-\theta_j}\right) - \ln\left(T_{njt}\left(c_{njt}\right)^{-\theta_j}\right) - \theta_j \ln d_{nijt}. \tag{2.9}$$

Last, construct a proxy for $\ln d_{nijt}$,

$$\ln d_{nijt} = dt_{knijt} + tm_{nijt} + bd_{nijt} + la_{nijt} + cl_{nijt} + lg_{nijt} + ta_{nijt} + cu_{nijt} + s_{ijt} + \epsilon_{nijt}, \tag{2.10}$$

where dt_{knijt}, $k = 1, ..., 6$, is the effect of geographic distance between n and i falls in the k-th bin, tm_{nijt} the effect of time zone difference, bd_{nijt} the effect of sharing border, la_{nijt} the effect of common official language, cl_{nijt} the effect of historical colonial ties, lg_{nijt} the effect of common legal system, ta_{nijt} the effect of in-force trade agreements, cu_{nijt} the effect of common currency union, s_{ijt} the exporter's fixed effect, and last but not least ϵ_{nijt} other effects that are unaccounted by the above. The six distance bins are $[0, 375)$, $[375, 750)$, $[750, 1500)$, $[1500, 3000)$, $[3000, 6000)$ and $[6000, \infty)$ in miles. I also make the simplifying assumption that each ϵ_{nijt} is i.i.d normal.

Combining equations 2.9 and 2.10 yields the final estimation equation

$$\begin{aligned} \ln\left(\frac{X_{nijt}}{X_{nnjt}}\right) = & \underbrace{-\theta_j\Big(dt_{knijt} + tm_{nijt} + bd_{nijt} + la_{nijt} + cl_{nijt} + lg_{nijt} + ta_{nijt} + cu_{nijt}\Big)}_{\text{Bilateral Dummy Variables}} \\ & \underbrace{\ln\Big(T_{ijt}\left(c_{ijt}\right)^{-\theta_j}\Big) - \theta_j s_{ijt}}_{\text{Exporter Fixed Effect}} \underbrace{- \ln\Big(T_{njt}\left(c_{njt}\right)^{-\theta_j}\Big)}_{\text{Importer Fixed Effect}} \underbrace{-\Big(\theta_j \epsilon_{nijt}\Big)}_{\text{Error Term}}. \end{aligned} \tag{2.11}$$

The above equation is estimated for each industry and time period separately, yielding an estimate of $T_{njt}\left(c_{njt}\right)^{-\theta_j}$ for each country, industry and time period. However, these estimates will be relative to a reference country, which is chosen to be the U.S.. Denote the estimated value by

$$S_{njt} = \frac{T_{njt}\left(c_{njt}\right)^{-\theta_j}}{T_{USjt}\left(c_{USjt}\right)^{-\theta_j}}. \tag{2.12}$$

2.3.2 Estimating U.S. Industry Productivity

To complete the estimation, the productivity of each industry in the U.S. need to be estimated. Let Λ_{USjt} be the average productivity of industry j in the U.S. in period t, the Cobb-Douglas production assumption implies that

$$\ln Z_{USjt} = \ln \Lambda_{USjt} + \beta_{USjt} \ln L_{USjt} + \left(1 - \beta_{USjt}\right) \sum_{l=1...J} \gamma_{USjlt} \ln \frac{M_{USjlt}}{P_{USlt}}, \tag{2.13}$$

where Z_{USjt} represents the units of output produced, L_{USjt} the labor input, and $\frac{M_{USjlt}}{P_{USlt}}$ the units of intermediate input from industry l embodied in the output of industry j. In the absence of trade, the average productivity of industry j in the U.S. is simply

$$(\Lambda_{USjt})^{\theta_j} = T_{USjt}$$

according to the Frechet assumption. However, when the economy is open, this needs to be adjusted to

$$(\Lambda_{USjt})^{\theta_j} = T_{USjt} + \sum_{i \neq U.S.} T_{ijt} \left(\frac{c_{ijt} d_{USijt}}{c_{USjt}} \right)^{-\theta_j} = T_{USjt} \sum_{i=1...I} S_{ijt} \left(d_{USijt} \right)^{-\theta_j}, \tag{2.14}$$

derived by Finicelli et al. (2013). Because S_{ijt} and d_{USijt} are already available after estimating equation 2.11, it is possible to compute T_{USjt} using equation 2.13 and 2.14.

Without sectoral price data, actual implementation requires an additional iterative step to solve for the equilibrium P_{USlt} in equation 2.13. Rewrite the price indices of the U.S. defined by equation 2.6 as

$$P_{USjt} = \Gamma_j \left[T_{USjt} \left(c_{USjt} \right)^{-\theta_j} \sum_{i=1}^{I} S_{ijt} \left(d_{USijt} \right)^{-\theta_j} \right]^{-\frac{1}{\theta_j}}, \tag{2.15}$$

where

$$c_{USjt} = (w_{USt})^{\beta_{USjt}} \prod_{l=1...J} (P_{USlt})^{\left(1-\beta_{USjt}\right)\gamma_{USjlt}}.$$

Equation 2.15 describes a system of equations from which the set of price indices $\{P_{USjt}\}_{j=1...J}$ can be solved for a given set of $\{T_{USjt}\}_j$. Thus, starting from an initial guess of $\{P_{USjt}\}_j$, the algorithm will iteratively compute the implied set of $\{T_{USjt}\}_j$ using equations 2.13 and 2.14, and update $\{P_{USjt}\}_j$ according to equation 2.15 until the price indices from two consecutive iterations are sufficiently close.

To compute T_{njt} for all other countries, it is most convenient to use the c_{USjt} and T_{USjt}

computed from the above and construct the unit costs by

$$c_{njt} = (w_{nt})^{\beta_{njt}} \prod_{l=1...J} (P_{nlt})^{(1-\beta_{njt})\gamma_{njlt}},$$

where

$$P_{njt} = \Gamma_j \left[T_{USjt} \left(c_{USjt} \right)^{-\theta_j} \sum_{i=1}^{I} S_{ijt} \left(d_{nijt} \right)^{-\theta_j} \right]^{-\frac{1}{\theta_j}}.$$

The final technology can be backed out from

$$T_{njt} = S_{njt} T_{USjt} \left(\frac{c_{USjt}}{c_{njt}} \right)^{-\theta_j}. \tag{2.16}$$

Next, this estimation method will be implemented using 17 years of industry-level bilateral trade flows and various other macro data. The estimated productivity will allow us to investigate the evolution of both absolute and comparative advantage across 40 countries and 35 broad industries including services.

2.4 Numerical Results and Counterfactuals

In this section, I will estimate the productivity for 35 industries in 40 countries from 1995 to 2011. Two major data sources are reference in the estimation process, the annual world input and output tables from the World Input-Output Database (WIOD) and a copy of Penn World Table 8.1 kept at the Groningen Growth and Development Centre (GGDC) Databases. The former is used to extract bilateral trade flows and the latter is used for additional macro data. Both sources offer free online access. Appendix A contains more details on the sources of data.

Questionable data quality is a common concern for quantitative analysis on services trade. Since the WIOD services trade data is derived from popular sources like UN Services Trade

Database, OECD and EuroStat, it inherits the data quality issues in the underlying sources. Current services flows are imputed from Balance of Payments accounts and re-mapped into ISIC classifications via correspondences. Due to the intangibility and non-storability nature of services, as well as less compilation efforts on BOP records, we expect lower accuracy in the measurements. Revisions in the correspondences add further inaccuracies into the industry aggregates. Confidentiality is another profound issue in services flows as reporters can suppress actual flow when a single producer contributes a significant share of total flow in a certain industry. This often results in higher percentage of missing flows in certain industries. Nevertheless, the WIOD does offer a few advantages over its underlying sources according to Timmer (2012). First, by referencing multiple sources, it is able to eliminate some apparent data errors and apply consistent industry correspondence across time, avoiding the need to reconcile time-varying industry definitions. Second, it directly links trade flows with production and input under the same set of industry definitions, eliminating the need of trade-production concordance. Third, it pre-computes the input, output, and trade flows for the rest of the world, offering a complete static snap shot of the world economy in each year.

The input and output tables allows simple computation of final demand shares α_{ijt}, value-added shares β_{ijt}, intermediate input shares γ_{iljt}, and total deficits D_{it}. In addition, industry absorption X_{ijt}, production Y_{ijt}, intermediate used M_{ijt} are also obtained from the input and output tables. Trade frictions are computed using the coefficients of equation 2.11. I used labor and human capital index from the Penn World Table to compute effective labor endowment. Wage w_{ijt} is obtained by dividing total value-added computed from the input and output tables by the human-capital augmented labor supply. Following Eaton and Kortum (2002) and Levchenko and Zhang (2011), I set $\theta_j = 8.28$ and $\sigma_j = 4$ for all industries. Results under alternative sector and industry-specific θ_j assumptions will be discussed at the end of the section.

Sample Countries	40
OECD	26
Non-OECD	14
Sample Labor Force Share	72.2%
Sample Output Share	87.7%
Sample GDP Share	84.0%
Sample Imports Share	81.0%
Agriculture	87.9%
Manufacturing	83.2%
Services	66.6%
Other	95.1%
Sample Exports Share	83.5%
Agriculture	70.1%
Manufacturing	86.8%
Services	89.8%
Other	43.6%

Source: WIOD input-output tables.

Table 2.1. Data Summary

A summary of the sample is presented in table 2.1. The sample contains 26 OECD countries and 14 major non-OECD economies. Together they constituted 87.7% of world's total output and over 80% of total trade. Note the imbalance in the contents of trade between our sample and the rest of the world: the sample countries ran a deficit in agriculture products and raw materials, a smaller surplus in manufacturing, and a larger surplus in services.

2.4.1 Fit of Gravity Regressions

Table 2.2 summarizes the results for the main estimation equation 2.11. On average, the model yields reasonable fit across industries, with a median adjusted R-squared at 78%. Notice that the agricultural (A) and manufacturing (M) industries have better fit compared to services (S) and other (O) industries. This is partially caused by the lower trade volume, higher percentage of missing trade flows, as well as the questionable quality of the available services trade data.

Industry	Sector	Description*	Average Adj. R^2	% of Missing Trade
AtB	A	Agriculture	78%	0%
15t16	M	Food	82%	0%
17t18	M	Textiles	80%	4%
19	M	Leather & Footwear	78%	0%
20	M	Wood	80%	1%
21t22	M	Paper & Printing	80%	0%
23	M	Coke & Petrol	78%	10%
24	M	Chemicals	82%	0%
25	M	Rubber & Plastic	84%	0%
26	M	Nonmetallic Mineral	81%	0%
27t28	M	Metals	81%	0%
29	M	Machinery	84%	2%
30t33	M	Electrical & Optical	80%	2%
34t35	M	Transport Equipment	82%	0%
36t37	M	Mics Manufacturing	80%	22%
C	O	Mining	74%	8%
E	O	Utilities	79%	14%
F	O	Construction	73%	4%
50	S	Fuel & Motor Trade	71%	8%
51	S	Wholesale Trade	77%	5%
52	S	Retail Trade	71%	6%
60	S	Inland Transport	70%	7%
61	S	Water Transport	79%	26%
62	S	Air Transport	76%	3%
63	S	Other Transport	72%	1%
64	S	Post & Telecom	63%	8%
70	S	Real Estate	65%	8%
71t74	S	Business Services	70%	18%
H	S	Hotels & Restaurants	71%	12%
J	S	Financial Services	65%	8%
L	S	Social Security	70%	20%
M	S	Education	69%	16%
N	S	Health & Social	67%	17%
O	S	Community & Personal	62%	9%
P	S	Private Households	69%	90%

Note: *See appendix A for full industry description.

Table 2.2. Fit of Gravity Equation 2.11 by Industry

Year	Agriculture	Manufacturing	Services	Others
1995	2.92	2.40	4.29	3.74
1996	2.92	2.38	4.07	3.79
1997	2.89	2.32	4.11	3.65
1998	2.85	2.29	4.14	3.64
1999	2.86	2.28	4.11	3.59
2000	2.85	2.24	4.02	3.54
2001	2.84	2.23	4.28	3.54
2002	2.85	2.21	3.91	3.43
2003	2.84	2.20	4.02	3.42
2004	2.85	2.18	3.77	3.39
2005	2.80	2.16	3.80	3.47
2006	2.76	2.14	3.55	3.37
2007	2.74	2.11	3.62	3.41
2008	2.73	2.10	3.42	3.40
2009	2.75	2.11	3.47	3.46
2010	2.73	2.11	3.75	3.53
2011	2.70	2.09	3.64	3.46

Note: Result assumes $\theta = 8.28$ for all industries and years.

Table 2.3. Sectoral Average Trade Frictions by Year

Table 2.3 presents the average trade barriers imputed from the estimation coefficients. Recall that a global θ_j is assumed for the baseline estimation. Under this assumption, services industries face higher barriers than other sectors, whereas manufacturing industries have the lowest average barriers. By comparing the 3-year average barriers of 1995-97 to those of 2009-11, overall trade barriers reduced by 12%, roughly 0.77% per annum. Services lead the reduction at 13%, followed by manufacturing's 12%. Agriculture and other industries only experienced 6% aggregate reduction. Table 2.4 further breaks it down by industries. Clearly, even though most industries experienced barrier reduction, its magnitude considerably varies across industries. The coefficient of variation for the friction reduction across industries is over 65%. Financial services and miscellaneous transportations stand out with minor increase in trade barriers.

Industry	Sector	Description	Trade Friction Reduction*
P	S	Private Households	33%
29	M	Machinery	18%
19	M	Leather & Footwear	17%
M	S	Education	16%
E	O	Utilities	16%
34t35	M	Transport Equipment	15%
O	S	Community & Personal	15%
52	S	Retail Trade	14%
30t33	M	Electrical & Optical	14%
24	M	Chemicals	13%
70	S	Real Estate	13%
51	S	Wholesale Trade	12%
36t37	M	Mics Manufacturing	12%
25	M	Rubber & Plastic	12%
50	S	Fuel & Moter Trade	12%
17t18	M	Textiles	11%
71t74	S	Business Services	11%
23	M	Coke & Petrol	11%
62	S	Air Transport	11%
N	S	Health & Social	10%
15t16	M	Food	8%
61	S	Water Transport	8%
27t28	M	Metals	7%
21t22	M	Paper & Printing	7%
20	M	Wood	7%
60	S	Inland Transport	6%
AtB	A	Agriculture	6%
26	M	Nonmetallic Mineral	5%
L	S	Social Security	5%
64	S	Post & Telecom	4%
F	O	Construction	1%
H	S	Hotels & Restaurants	1%
C	O	Mining	1%
J	S	Financial Services	-1%
63	S	Other Transport	-1%

Note: *Reduction based on ratio of 3-year average friction of 1995-97 and 2009-11.

Table 2.4. Average Trade Friction Reduction by Industry, 1995 - 2011

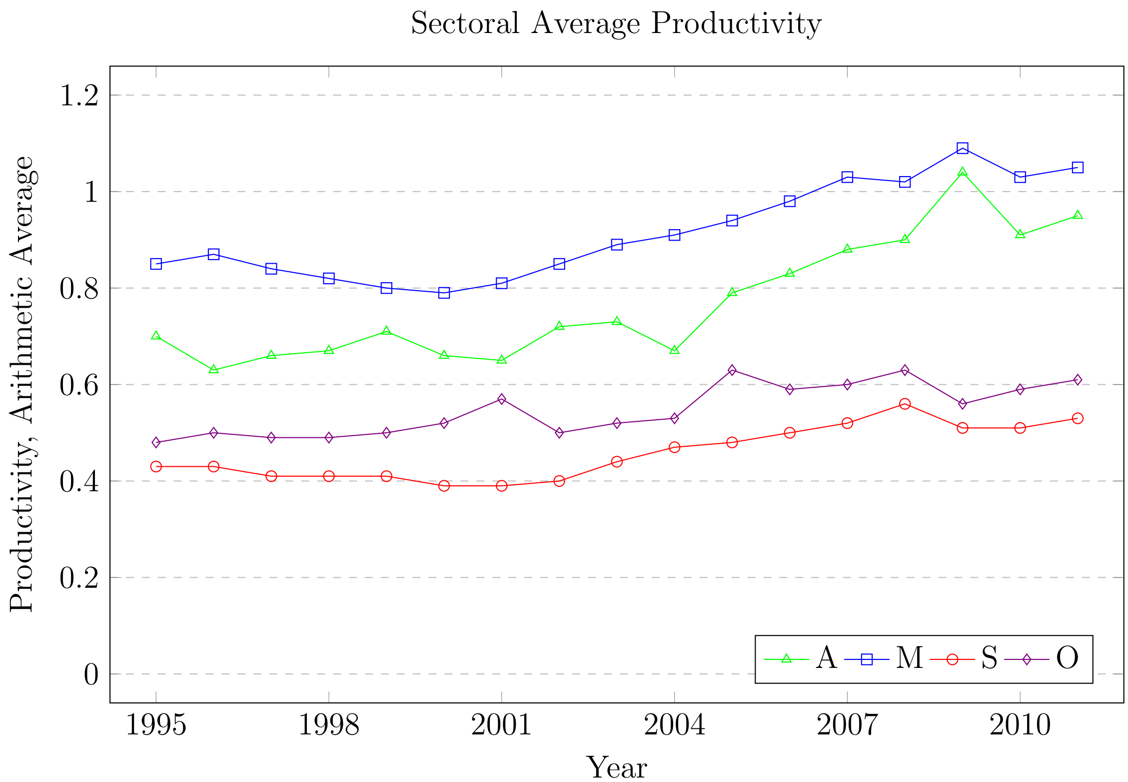


Figure 2.1. Sectoral Average Productivity by Year

2.4.2 Basic Patterns in Estimated Productivities

Figure 2.1 plots the average estimated productivity for each sector over time. The average is computed by taking the arithmetic average across industries and countries in each year. Manufacturing had the highest average productivity while services stayed at the bottom throughout the period. All sectors experienced absolute productivity growth. Agriculture had the highest average growth rate at nearly 2.2% per year, followed by 1.7% of manufacturing. Average annual growth of services and other industries productivity was only 0.9%.

Despite the apparent gap in growth rates across sectors, the productivity difference between OECD and non-OECD countries is shrinking in all sectors. Figure 2.2 plots the ratio of average sectoral productivity of OECD countries and non-OECD countries. It is obvi-

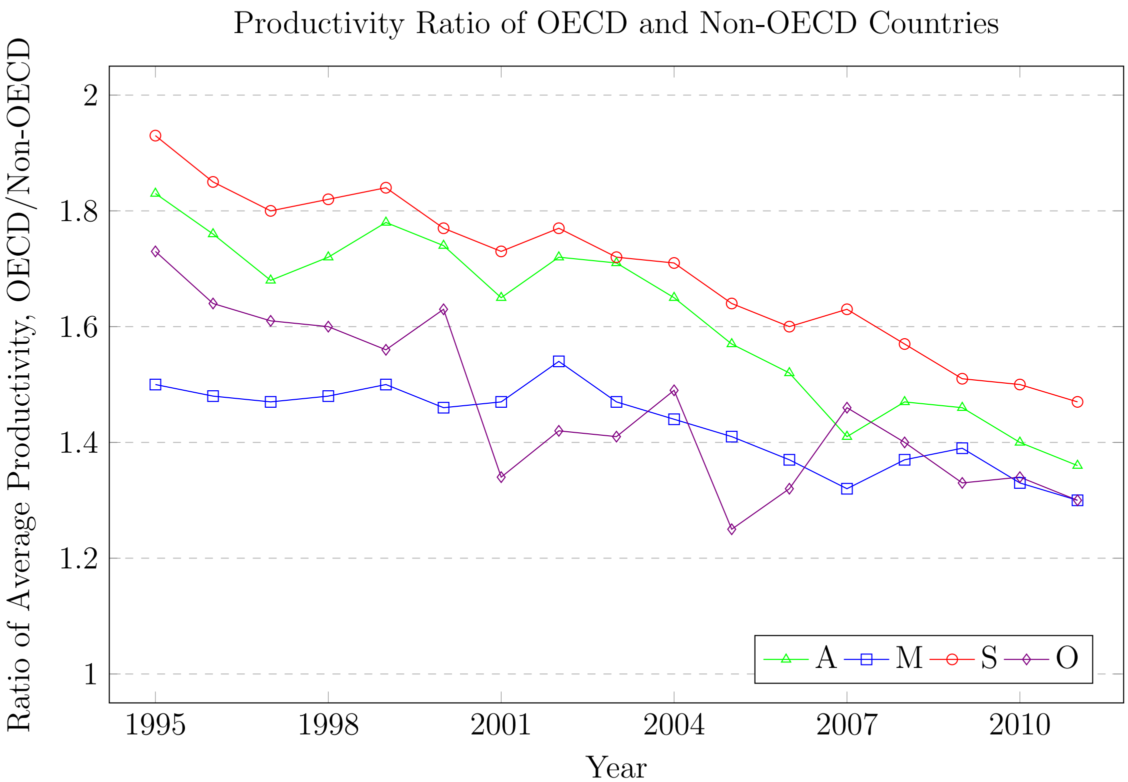


Figure 2.2. Productivity Ratio of OECD and Non-OECD Countries by Year

ous that the productivity advantage of the OECD countries has diminished over the period. Agriculture and services experienced the most gap reduction, at 2.74% and 2.61% per annum respectively. The gap in manufacturing is reducing at a slower speed, 1.19% per year.

Figure 2.3 looks at the ratio of average productivity of manufacturing to services in OECD and non-OECD countries. Non-OECD countries had a clear comparative advantage in manufacturing throughout the period. However, the comparative advantage had become unmistakably weaker at the end of the period. By normalizing the maximum manufacturing to services productivity ratio across countries to 1, figure 2.4 reveals strong relative convergence in the sample over the period. Standard deviation of the average manufacturing to services productivity ratio across countries decreased from 0.35 to 0.2 – a strong signal of weakend comparative advantage.

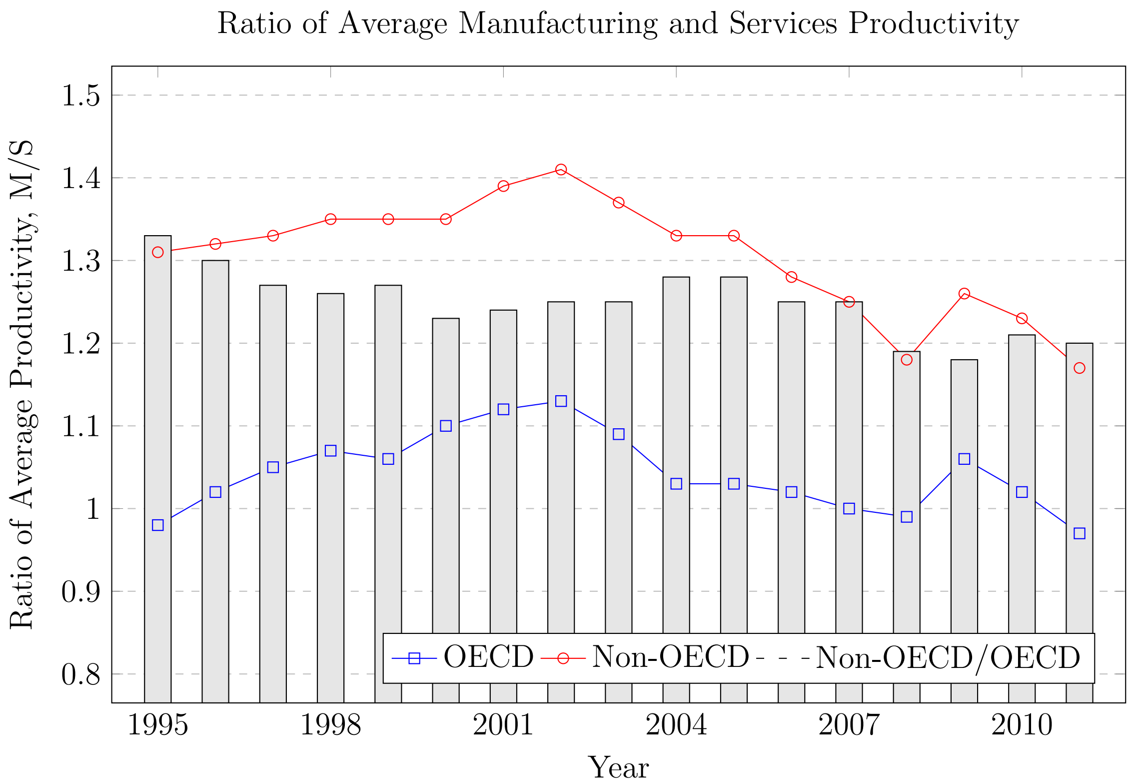


Figure 2.3. Ratio of Average Productivity, Manufacturing to Services by Year

All in all, these basic patterns indicate both absolute growth and relative convergence across countries and sectors in the sample. While the observed absolute and catch-up growth led to straight forward welfare gains especially among non-OECD countries, the impact of the relative convergence and the weakened comparative advantage needs a closer look.

2.4.3 Relative Productivity Convergence

To better quantify the evolution of comparative advantage across countries and industries, I will follow Levchenko and Zhang (2011) and Barro and Sala-i-Martin (1992) to estimate the following relative convergence specification:

$$\ln\left(\frac{T_{nj(t+\Delta t)}}{T_{njt}}\right)^{\frac{1}{\theta_j}} = \kappa \ln\left(T_{njt}\right)^{\frac{1}{\theta_j}} + \lambda_n + \lambda_j + \epsilon_{njt}. \tag{2.17}$$

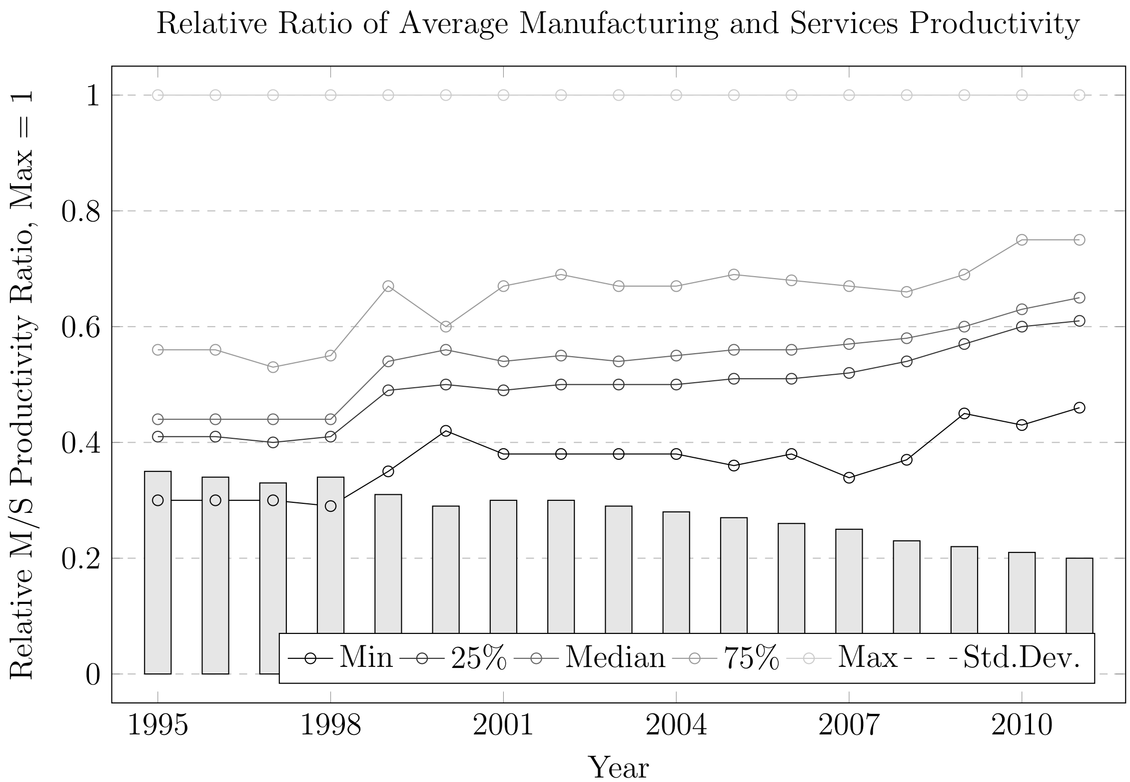


Figure 2.4. Distribution of Relative Ratio of Average Productivity, Manufacturing to Services by Year

The log change in average industry productivity on the left-hand side is regressed on the initial average industry productivity on the right-hand side. The inclusion of country fixed effect on the right will absorb the average change in productivity across all industries in each country. Likewise, the industry fixed effect will absorb the average change in productivity across all countries in each industry. The remaining coefficient κ thus captures the impact of initial productivity on the relative growth of industry productivity. Hence it can be interpreted as a direct measure on the evolution of comparative advantage. A negative κ indicates that the most backward industry grew fastest, narrowing cross-industry productivity difference and weakening comparative advantage. Figure 2.5 plots the negative correlation between productivity growth and initial productivity in our pooled sample. This

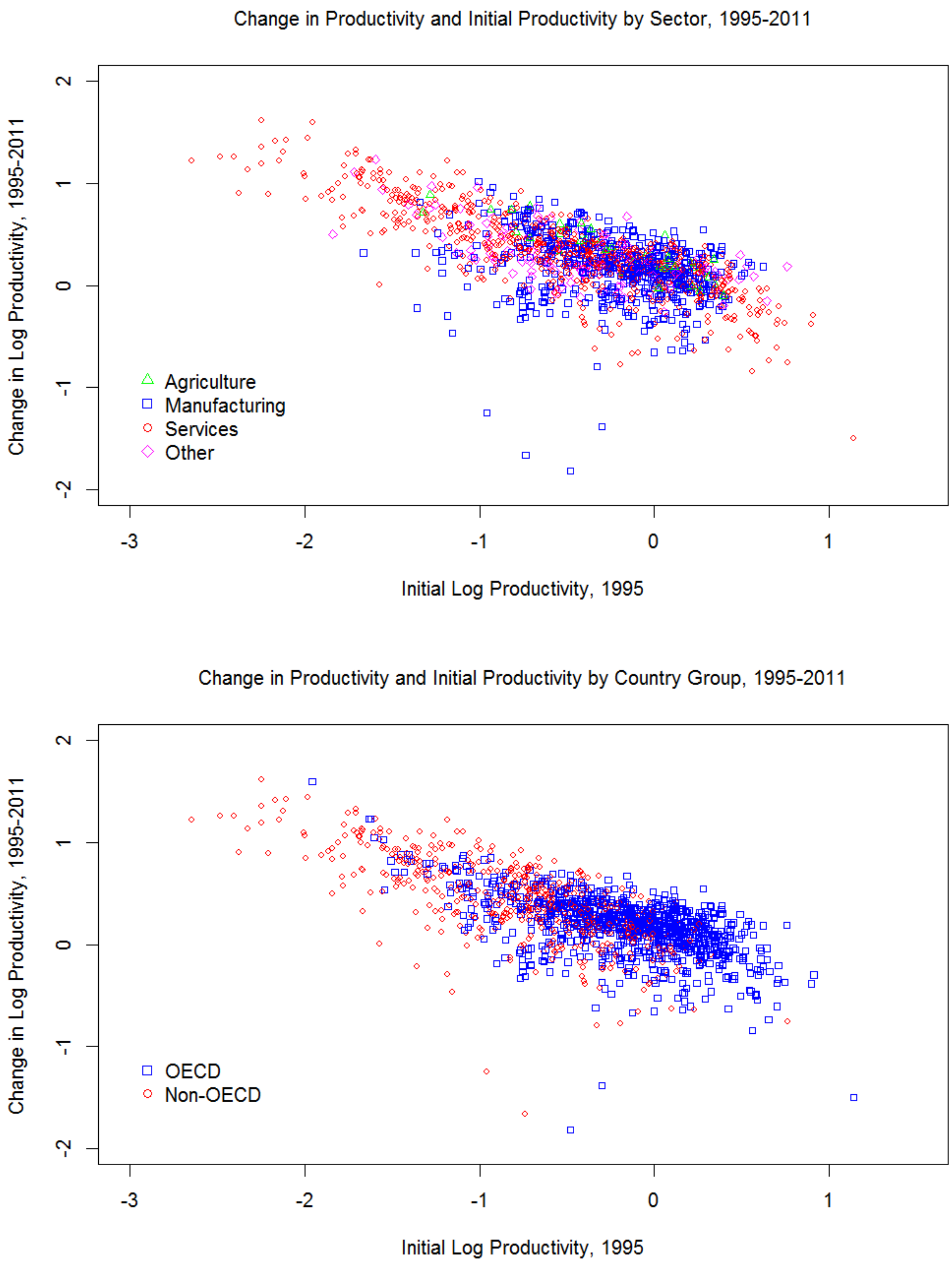


Figure 2.5. Relative Productivity Convergence By Country Group and Sector, 1995-2011.

Period	κ	S.E.	Adj. R^2	λ_κ	λ_n	λ_j
All Countries						
1995-2011	-0.434	0.021	82%	3.4%	-0.6%	-0.1%
1995-2000	-0.222	0.021	55%	4.2%	0.6%	1.8%
2000-2005	-0.301	0.017	66%	5.9%	-1.8%	0.9%
2005-2010	-0.192	0.016	64%	3.6%	0.1%	-0.7%
OECD Countries						
1995-2011	-0.389	0.032	75%	2.9%	-0.5%	-0.1%
1995-2000	-0.237	0.022	71%	4.5%	0.2%	1.7%
2000-2005	-0.120	0.023	67%	2.1%	-2.3%	0.0%
2005-2010	-0.157	0.020	61%	2.8%	0.3%	-0.8%
Non-OECD Countries						
1995-2011	-0.494	0.034	85%	4.0%	-0.5%	0.1%
1995-2000	-0.216	0.045	43%	4.1%	1.1%	2.1%
2000-2005	-0.453	0.026	74%	10.1%	0.3%	2.8%
2005-2010	-0.192	0.032	66%	3.5%	-0.1%	-0.8%
Manufacturing Industries						
1995-2011	-0.339	0.060	74%	2.4%	-0.6%	0.2%
1995-2000	-0.151	0.075	35%	2.7%	0.4%	1.3%
2000-2005	-0.312	0.030	67%	6.2%	-1.2%	1.5%
2005-2010	-0.241	0.035	47%	4.6%	0.1%	-0.3%
Services Industries						
1995-2011	-0.506	0.031	86%	4.2%	-0.4%	-0.3%
1995-2000	-0.228	0.023	73%	4.3%	4.2%	-0.7%
2000-2005	-0.264	0.022	78%	5.1%	-1.9%	0.3%
2005-2010	-0.160	0.024	75%	2.9%	-0.5%	-0.7%

Note: Column λ_n and λ_j contains average annualized country and industry fixed effects.

Table 2.5. Relative Productivity Convergence in Equation 2.17

pattern holds for each of the four sectors and both country groups.

To better interpret κ, it is convenient to calculate the implied speed of convergence using the standard Barro and Sala-i-Martin (1992) formula

$$\kappa = \exp(-\lambda_\kappa \Delta t) - 1$$

where λ_κ is the annualized speed of convergence and Δt is the time difference in years between the final and initial productivity measurement. λ_κ represents the amount of initial productivity difference that is expected to disappear every year. Table 2.5 summarizes the estimation results for equation 2.17 and the implied speed of convergence. There are five panels in the table. The first panel pools all countries and all industries. The second and third panels compares country groups by pooling just the OECD countries and the non-OECD countries. The last two panels are separated by the manufacturing and services sector. In each panel, I estimated the speed of convergence over the entire 17-year period from 1995-2011, as well as the 3 five-year periods starting at 1995, 2000 and 2005. Also reported in the table are the estimated κ, its standard errors, the adjusted R-squared of the regression, and the average annualized country and industry fixed effects. Average annual convergence was 3.4% over the entire period. Convergence among non-OECD countries was 1% faster than OECD countries, and services industries caught up 1.6% faster than manufacturing industries. The five-year period results further confirmed the convergence trend in different intervals of the period but with noticeable amount of fluctuations caused by the inter-temporal volatility embedded in the productivity estimates. Note that the 2.4% annual convergence rate for manufacturing industries is comparable to the 1.8% and 2.2% from Levchenko and Zhang (2011) and Barro and Sala-i-Martin (1992) respectively.

An easy extension is to let κ and λ_κ vary across countries and industries. The country specific version, κ_n and $\lambda_{\kappa,n}$, will measure the speed of convergence across different industries within each country n, while the industry specific version, κ_j and $\lambda_{\kappa,j}$, shows the speed of convergence across countries for each industry j. Table 2.6 shows the industry specific speed of convergence. All industries experienced statistically significant convergence from 1995 to 2011 but with very different magnitudes. Coke, petroleum refinement, transportation, and telecommunications has the fastest convergence at over 5% annually, while leather and footwear manufacturing only had 0.3%. The average speed across industries was 3.5% with a coefficient of variation of 29%. Consistent with Table 2.5, services industries experienced

Industry	Sector	κ_j	S.E.	$\lambda_{\kappa,j}$
23	M	-0.621	0.101	5.7%
61	S	-0.603	0.059	5.4%
63	S	-0.586	0.059	5.2%
64	S	-0.567	0.046	4.9%
60	S	-0.557	0.055	4.8%
E	O	-0.546	0.077	4.6%
62	S	-0.507	0.067	4.2%
J	S	-0.495	0.048	4.0%
AtB	A	-0.494	0.064	4.0%
20	M	-0.491	0.106	4.0%
34t35	M	-0.491	0.092	4.0%
71t74	S	-0.479	0.050	3.8%
36t37	M	-0.474	0.088	3.8%
27t28	M	-0.460	0.092	3.6%
30t33	M	-0.456	0.078	3.6%
25	M	-0.454	0.089	3.6%
15t16	M	-0.448	0.105	3.5%
70	S	-0.438	0.040	3.4%
C	O	-0.437	0.061	3.4%
F	O	-0.433	0.067	3.3%
51	S	-0.428	0.049	3.3%
O	S	-0.422	0.059	3.2%
26	M	-0.405	0.084	3.1%
M	S	-0.404	0.041	3.0%
21t22	M	-0.397	0.074	3.0%
17t18	M	-0.392	0.103	2.9%
24	M	-0.390	0.086	2.9%
52	S	-0.389	0.048	2.9%
P	S	-0.388	0.040	2.9%
29	M	-0.381	0.074	2.8%
L	S	-0.380	0.043	2.8%
H	S	-0.368	0.058	2.7%
50	S	-0.354	0.045	2.6%
N	S	-0.297	0.054	2.1%
19	M	-0.056	0.099	0.3%

	Average $\lambda_{\kappa,j}$	Coef. of Variation
All Industries	3.5%	29%
Manufacturing	3.3%	34%
Services	3.6%	28%

Note: All estimates are significant at 1%.

Table 2.6. Speed of Productivity Convergence by Industry, 1995 - 2011

Country	OECD	κ_j	S.E.	$\lambda_{\kappa,n}$
KOR	Yes	-0.712	0.081	7.3%
SVK	Yes	-0.672	0.066	6.6%
ROM	No	-0.653	0.058	6.2%
LVA	No	-0.639	0.065	6.0%
EST	No	-0.553	0.071	4.7%
LTU	No	-0.549	0.063	4.7%
CZE	Yes	-0.525	0.075	4.4%
RUS	No	-0.523	0.076	4.4%
POL	Yes	-0.486	0.076	3.9%
BGR	No	-0.454	0.058	3.6%
DNK	Yes	-0.437	0.071	3.4%
TUR	Yes	-0.436	0.090	3.4%
AUS	Yes	-0.434	0.101	3.3%
FIN	Yes	-0.421	0.081	3.2%
HUN	Yes	-0.413	0.073	3.1%
IND	No	-0.413	0.042	3.1%
CYP	No	-0.399	0.072	3.0%
AUT	Yes	-0.399	0.085	3.0%
JPN	Yes	-0.390	0.109	2.9%
ESP	Yes	-0.387	0.091	2.9%
CHN	No	-0.387	0.054	2.9%
IRL	Yes	-0.381	0.081	2.8%
SVN	No	-0.379	0.079	2.8%
MEX	Yes	-0.367	0.079	2.7%
RoW	No	-0.366	0.071	2.7%
PRT	Yes	-0.363	0.089	2.7%
IDN	No	-0.360	0.061	2.6%
GBR	Yes	-0.343	0.103	2.5%
DEU	Yes	-0.341	0.086	2.4%
FRA	Yes	-0.333	0.087	2.4%
BEL	Yes	-0.327	0.079	2.3%
NLD	Yes	-0.319	0.087	2.3%
ITA	Yes	-0.307	0.084	2.2%
USA	Yes	-0.306	0.103	2.2%
SWE	Yes	-0.280	0.089	1.9%
MLT	No	-0.269	0.094	1.8%
BRA	No	-0.268	0.089	1.8%
GRC	Yes	-0.264	0.083	1.8%
CAN	Yes	-0.263	0.106	1.8%
TWN	No	-0.249	0.091	1.7%
LUX	Yes	-0.001	0.068	0.0%

	Average $\lambda_{\kappa,n}$	Coef. of Variation
All Countries	3.2%	45%
OECD	3.0%	45%
Non OECD	3.5%	41%

Note: All estimates are significant at 1%.

Table 2.7. Speed of Productivity Convergence by Country, 1995 - 2011

stronger convergence than manufacturing. Table 2.7 presents a similar view across countries. Korea had the highest convergence growth across industries during the period. Luxembourg had almost no convergence across industries. On average, Non-OECD countries appear to have faster convergence than OECD countries.

In short, these results support relative convergence across all countries and industries in the sample. Less productive industries grew faster during the entire period and each sub intervals. Comparative advantage was weakened not only among manufacturing industries, but also in other parts of the world economy.

2.4.4 Random Diffusion and Relative Convergence

Let by Alvarez et al. (2013) among others, recent development in the growth literature proposed a simple random diffusion mechanism that is capable of generating convergence growth across industries and countries. In particular, suppose a producer with productivity z drawn from the Frechet distribution $F_{ijt}(z)$ can randomly meet with producers from other Frechet distributions $G^{\Phi}_{ijt}(z)$, with $\Phi = \mathrm{I}, \mathrm{II}, \mathrm{III}...\Xi$, and exchange ideas $\eta_{\Phi} \geq 0$ times per period. After each meeting, both producers will adopt the better of their productivities and thus improve cost efficiency. In such settings, producers with lower productivity will be more likely to meet with more efficient producers and improve techniques, whereas producers with higher productivity are less likely to improve. As a result, better techniques will diffuse across the economy. Depending on the assumptions on the sources for $G_{ijt}(z)$, this mechanism can generate convergence across countries, industries or both. Moreover, Alvarez et al. (2013) proved that on a balanced growth path, the equilibrium productivity distribution must be in the Frechet family. In other words, it is possible to define the dynamics of $F_{ijt}(z)$ by

$$
\begin{aligned}
F_{ij,t+1}(z) &= \exp\left(-T^F_{ij,t+1} z^{-\theta_j}\right) \\
&= F_{ijt}(z) \prod_{\Phi=I}^{\Xi} \left(G^\Phi_{ijt}(z)\right)^{\eta_\Phi} \\
&= \exp\left(-T^F_{ijt} z^{-\theta_j}\right) \prod_{\Phi=I}^{\Xi} \left[\exp\left(-\eta_\Phi T^\Phi_{ijt} z^{-\theta_j}\right)\right] \\
&= \exp\left(-\left(T^F_{ijt} + \sum_{\Phi=I}^{\Xi} \eta_\Phi T^\Phi_{ijt}\right) z^{-\theta_j}\right).
\end{aligned}
$$

Taking logarithm results in the following productivity evolution

$$
T^F_{ij,t+1} - T^F_{ijt} = \sum_{\Phi=I}^{\Xi} \eta_\Phi T^\Phi_{ijt}.
$$

With different assumptions on T^Φ_{ijt}, it is possible to estimate the speed of diffusion in different directions.

Inspired by the above theory, this section estimates the speed of technological diffusion across industries within each country and across countries for each industry by considering the following specification

$$
T_{ij,t+\Delta t} - T_{ijt} = \eta_0 + \eta_t T_{ijt} + \eta_j \sum_{l=1}^{J} T_{ilt} + \eta_n \sum_{n=1}^{I} T_{njt} + \epsilon_{ijt}, \tag{2.18}
$$

where η_0 picks up the average change in productivity from t to $t + \Delta t$, η_t controls for the dependence of change in productivity on initial productivity and time, η_j measures the speed of diffusion across industries within the country, η_n measures the speed of international diffusion. Higher values of η_j and η_n indicates faster diffusion. As the previous section has shown that initial productivity has a negative impact on change in productivity, we expect η_t to be negative.

Specification	η_j	η_n	η_t	Adjusted R^2
Without Time Fixed Effect				
Baseline: T_{ijt} Only			-0.680	50%
			***(0.005)	
with $\sum_{l=1}^{J} T_{ilt}$	0.081		-0.684	51%
	***(0.022)		***(0.005)	
with $\sum_{n=1}^{I} T_{njt}$		0.107	-0.685	51%
		***(0.023)	***(0.005)	
with Both	0.083	0.108	-0.689	51%
	***(0.022)	***(0.023)	***(0.005)	
With Time Fixed Effect				
Baseline: T_{ijt} Only			–	68%
			–	
with $\sum_{l=1}^{J} T_{ilt}$	0.036		–	69%
	*(0.018)		–	
with $\sum_{n=1}^{I} T_{njt}$		0.060	–	69%
		**(0.018)	–	
with Both	0.037	0.060	–	69%
	*(0.018)	**(0.018)	–	
Trade & Input-Output Adjustment	-0.008	0.065	–	69%
	(0.017)	**(0.020)	–	
Country & Industry Frontier	0.001	0.007	–	69%
	(0.002)	***(0.002)	–	
Country & Industry Fixed Effects	0.048	-0.035	–	69%
	*(0.024)	(0.024)	–	

Table 2.8. Speed of Technological Diffusion

Table 2.8 presents the estimated speed of diffusion with standard errors under different versions of equation 2.18. The top panel shows the coefficient estimates without any time fixed effects. The estimated speed of diffusion across industries within a country is over 8.1%, and the speed of international diffusion for industries is over 10%. All estimates are highly significant. In the second panel, I allowed η_0 and η_t to interact with the time dummy variable. This reduced η_j and η_n to 3.6% and 6.0% respectively. While these estimated diffusion speeds are still significant, the level of significance is slightly weakened. I omitted the η_t estimates in the table as there are too many. The bottom panel included three additional exercises. The first exercise replaced the simple sums $\sum_{l=1}^{J} T_{ilt}$ and $\sum_{n=1}^{I} T_{njt}$ with the weighted sums using the input-output shares γ_{iljt} and trade shares π_{nijt} as weights respectively. These adjustments produced 6.5% cross-border diffusion but rendered within-country diffusion insignificant. Similar results were obtained in the second exercise where the sums are replaced by the productivity frontiers for the corresponding country and industry. The third exercise added country and industry dummies to the estimation, but almost all dummies are statistically insignificant.

Last but not least, it is also worth mentioning that although η_j and η_n obtained in the first two panels are positive and significant, they do not offer much improvement to the overall fit of the model. Compared to the baseline, the adjusted R-squared only slightly improved after including these variables, and the fit was far from perfect. Therefore, while these results are consistent with the random diffusion mechanism, they also indicate potential inadequacy of such mechanisms.

2.4.5 The Missing Gains from Trade

The most important consequence of weakened comparative advantage is the potential diminution of gains from trade. To quantify the missing gains from trade due to relative convergence, this section compares the equilibrium welfare under the observed productivities of 2011 to the counterfactual welfare assuming all industry within each country grew at the same constant speed since 1995. This constant speed for every country is set to match the observed geometric average growth rate across its industries. The counterfactual productivities thus project the level comparative advantage of 1995 to 2011. Combined with the much lowered trade frictions, we can expect much higher trade intensity and gains from trade.

I follow the algorithm described in Appendix B to solve for the equilibrium. The numeraire is set to be observed U.S. GDP per labor unit in 2011. The baseline equilibrium uses

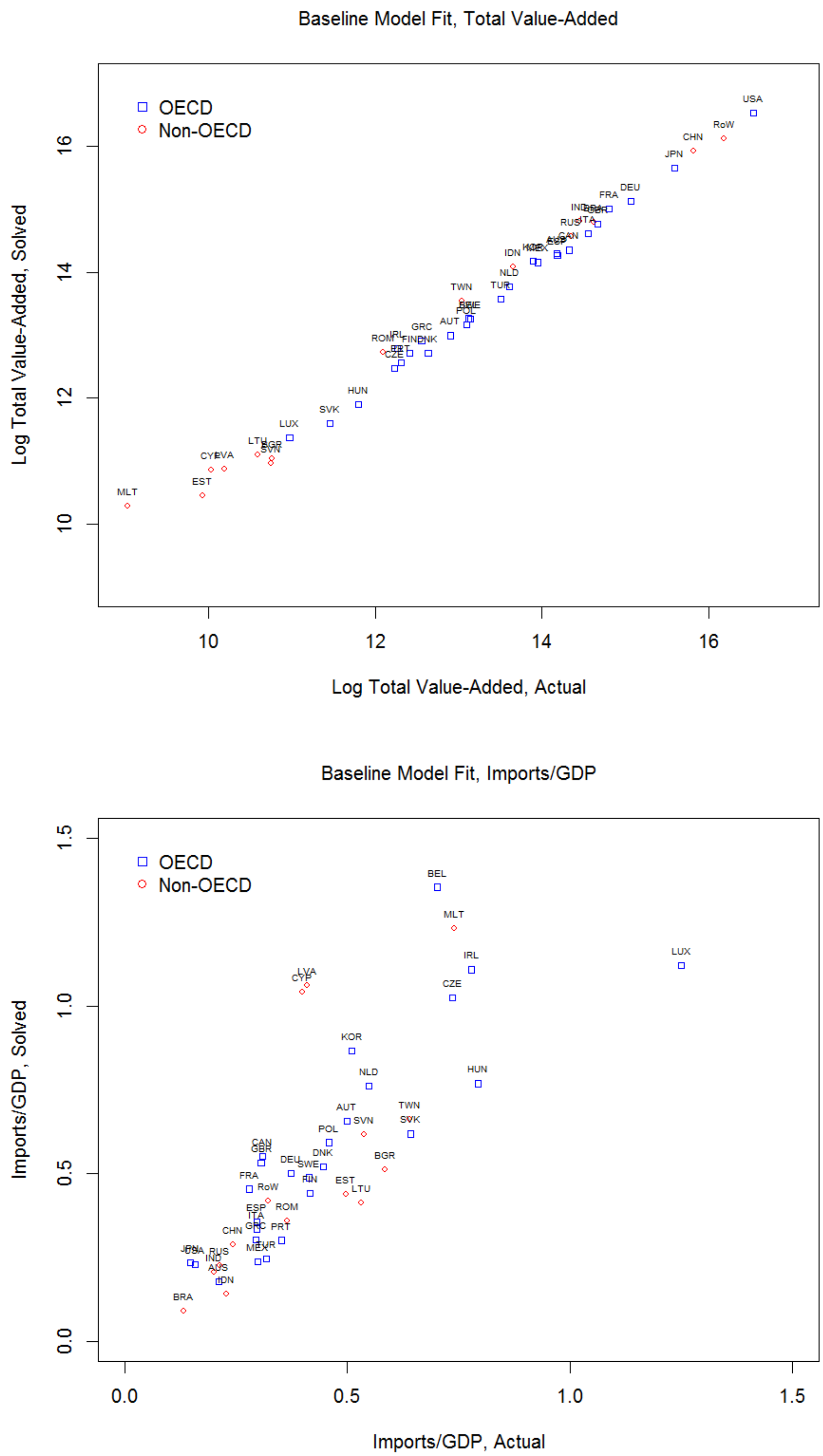


Figure 2.6. Baseline Model Fit, 2011

the estimated T_{ijt} of 2011. With the additional iterative step in the productivity estimation process, the model solution fits the baseline income very well. Figure 2.6 plots the solution income and imports/GDP against the observed counterparts for 2011. The correlation for income is over 99%. While the actual average imports/GDP was 26.5% in the sample, the baseline model predicts it to be 34.5% as it includes additional flows missing in the data. By forcing the flows that are missing in the data to zero, the predicted average imports/GDP drops to 29.2%.

The counterfactual equilibrium on the other hand assumes the following productivity in 2011

$$\tilde{T}_{ij,2011} = T_{ij,1995} \times \frac{T_{fj,2011}}{T_{fj,1995}} \times \frac{\left(\prod_{l=1}^{J} \frac{T_{il,2011}}{T_{fl,2011}}\right)^{\frac{1}{J}}}{\left(\prod_{l=1}^{J} \frac{T_{il,1995}}{T_{fl,1995}}\right)^{\frac{1}{J}}}$$

where T_{fjt} represents the productivity frontier of sector j in period t and is calculated by taking the geometric average of the first and second largest T_{ijt}. The second term on the right-hand side adjusts for the progress in the frontier, and the third term adjusts for the country-specific absolute growth relative to the frontier. The relative distance to the frontier across different industries thus remain unchanged in each country under this assumption. As a result, the counterfactual productivities preserve the comparative advantage of 1995.

Table 2.9 tabulates the additional gains from trade for each country under the counterfactual comparative advantage. Average gains from trade in 2011 would increase by 3.9% under the preserved comparative advantage of 1995. The average gain in both country group are similar, but OECD would have a higher median gain at 4.1% compared to the 3.4% median of non-OECD countries. These gains are significantly higher than the counterparts obtained by Levchenko and Zhang (2011) for the period from 1960 to 2000 with only manufacturing trade. The average imports/GDP would increase from 35% to 43%, a 22% increase. Imports of non-OECD countries would increase by 28%, 9% more than OECD countries. Again,

Country	OECD	Missing Gains from Trade	Increase in Imports/GDP
CHN	No	19.6%	19%
KOR	YES	12.2%	70%
SVK	YES	11.7%	-4%
IRL	YES	11.7%	42%
LTU	No	11.2%	-23%
TWN	No	10.5%	3%
RoW	No	9.7%	30%
POL	YES	8.1%	29%
CAN	YES	8.0%	78%
HUN	YES	7.1%	-3%
JPN	YES	6.7%	59%
IND	No	6.1%	3%
DNK	YES	5.7%	17%
CZE	YES	5.4%	39%
CYP	No	4.8%	160%
PRT	YES	4.7%	-14%
USA	YES	4.6%	45%
GBR	YES	4.5%	74%
AUS	YES	4.4%	-16%
BRA	No	4.0%	-33%
MEX	YES	3.8%	-20%
ESP	YES	3.4%	21%
RUS	No	3.4%	6%
NLD	YES	3.1%	39%
FIN	YES	1.7%	6%
SWE	YES	1.6%	18%
TUR	YES	1.4%	-23%
BGR	No	0.2%	-12%
BEL	YES	-0.1%	93%
MLT	No	-0.3%	66%
DEU	YES	-0.5%	34%
GRC	YES	-0.7%	3%
ITA	YES	-0.8%	13%
EST	No	-1.1%	-12%
FRA	YES	-1.8%	63%
ROM	No	-1.8%	-2%
AUT	YES	-1.9%	31%
SVN	No	-1.9%	14%
LVA	No	-2.0%	159%
LUX	YES	-3.2%	-10%
IDN	No	-4.3%	-38%

	Average Gain	Std.Dev.	Average Increase	Std.Dev.
All Countries	3.9%	5.2%	25%	45%
OECD	3.9%	4.3%	26%	33%
Non OECD	3.9%	6.6%	23%	61%

Table 2.9. Missing Gains from Trade Due to Relative Convergence, 1995 - 2011

Specification	Arithmetic Mean	Standard Deviation	Correlation w Baseline
Baseline	0.868	0.379	100.0%
Sector θ_j	0.822	0.364	97.6%
Industry θ_j	0.845	1.977	17.9%
Global IO	0.870	2.035	18.4%

Table 2.10. Robustness and Discussions

with the inclusion of services, we would observe higher growth in trade volume than the 15% predicted in Levchenko and Zhang (2011).

2.4.6 Robustness

The results presented so far assumes a global θ_j and country specific input and output structures. As a reference of the robustness of the productivity estimates to these assumptions, table 2.10 presents the mean, standard deviation and correlation with the baseline estimates for three alternative assumptions. The first alternative assumes sector-specific θ_j. In particular, I set $\theta_M = 5$ for manufacturing industries and $\theta_S = 9$ for services industries according to the estimates obtained in chapter 1, and kept θ_j for all other industries unchanged at 8.28. This alternative produced similar estimates to the baseline with a correlation over 97%. The top right plot in figure 2.7 shows distinct but consistent spikes in the new estimation caused by the change in θ_j for each sector. Next, I further relaxed θ_j to be industry-specific by utilizing the results of Caliendo and Parro (2009) for manufacturing industries, and set $\theta_j = 9$ for services industries and 8.28 for all other industries. The productivity estimates under this alternative specification become messier in comparison with the baseline. The estimation process produced extreme outliers for small-sized countries like Estonia, Latvia, Luxembourg and Malta that have high skews in their industrial composition of output and trade flows. These outliers significantly raised the standard deviation and lowered the correlation. However, as shown in the bottom-left plot of figure 2.7, the majority estimates

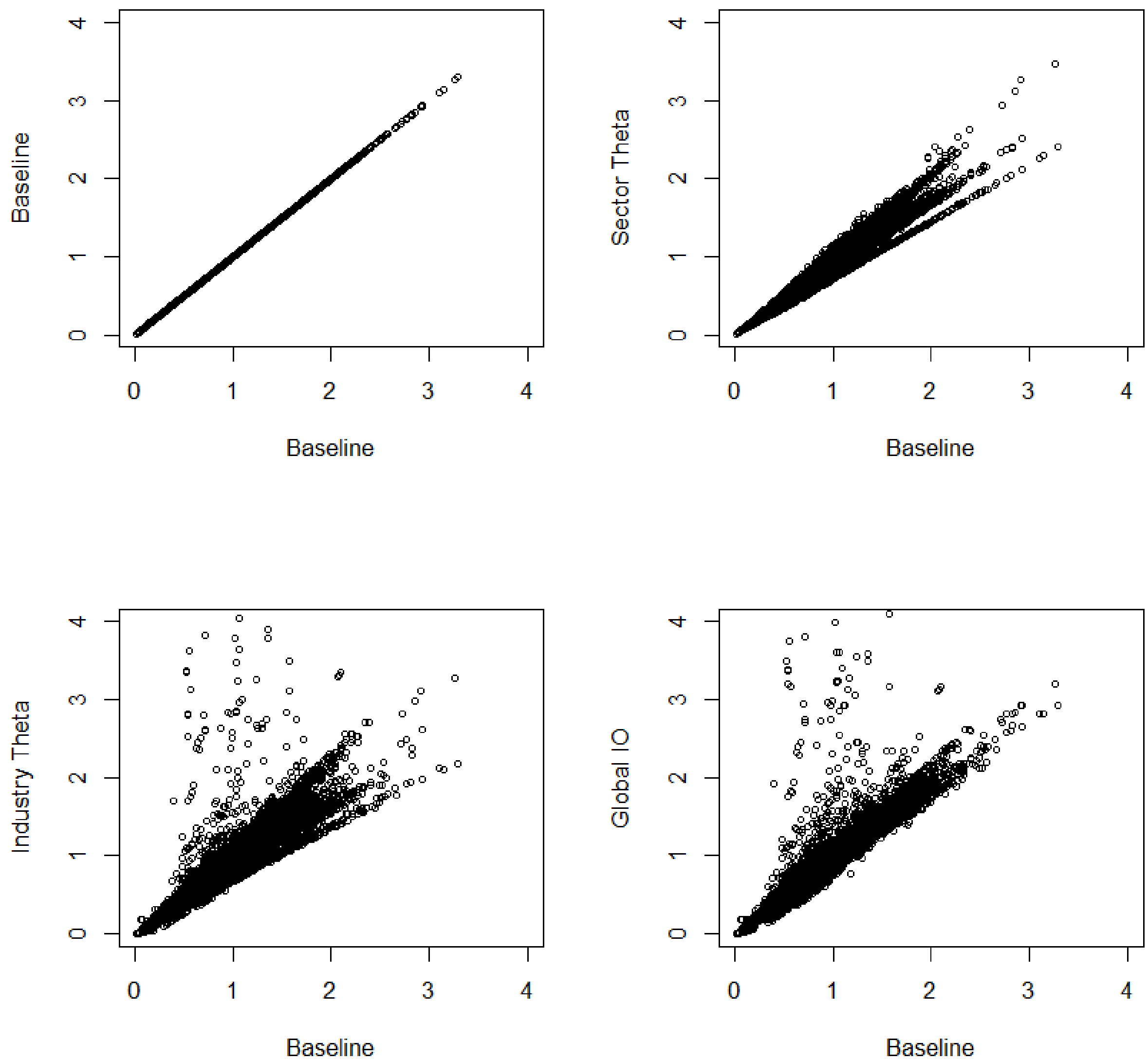


Figure 2.7. Correlation of Alternative Productivity Estimates with Baseline

reflected the adjustment in θ_j rather reasonably.[4] Increased variation in θ_j of manufacturing industries created more spikes compared to the previous plot. Lastly, I re-estimated productivities using a global input-output table. Specifically, β_{jt} and γ_{ljt} were computed from the

[4]For better visualization, the bottom plots of figure 2.7 exclude the extreme outliers beyond the limit of y axis.

world total input and output table instead of the country level ones. This specification also resulted in extreme outliers, especially in smaller countries with uneven industrial composition. Apart from the outliers, the majority of the estimates were reasonably consistent with the baseline. However, there is no distinct spikes in the plot because the changes are not uniform to each industry in different countries.

2.5 Conclusion

By estimating the productivity level for 35 industries in 40 countries from 1995 to 2011, this chapter established clear evidences of weakened comparative advantage beyond the manufacturing sector. In fact, the estimated relative convergence was faster outside the manufacturing sector. In the counterfactual experiment, the weakening of comparative advantage over the period took away 3.9% of unrealizable welfare gains from an average country. The inclusion of trade in services industries allows us to measure the additional gains from trade that were unaccounted for in the existing literature. It also provides a more comprehensive view of the evolution of comparative advantage in the economy. As the period in this study is more recent, these results extend the existing studies, and in the meantime, validate the persistent trend of relative convergence in productivity growth across countries and industries. Although our results support random diffusion as a mechanism for relative convergence, they do not rule out other possibilities. One potential future direction is thus to identify other empirical factors to establish further evidence for mechanisms that are driving convergence growth. In addition, studies like Hanson et al. (2015) has offered a dynamic perspective on the evolution of comparative advantage that focuses on the long run stationarity instead of convergence. As more granular data on services trade become available, validating and estimating the stationary distribution comparative advantage with services can be another interesting future direction to continue the discussion of this topic.

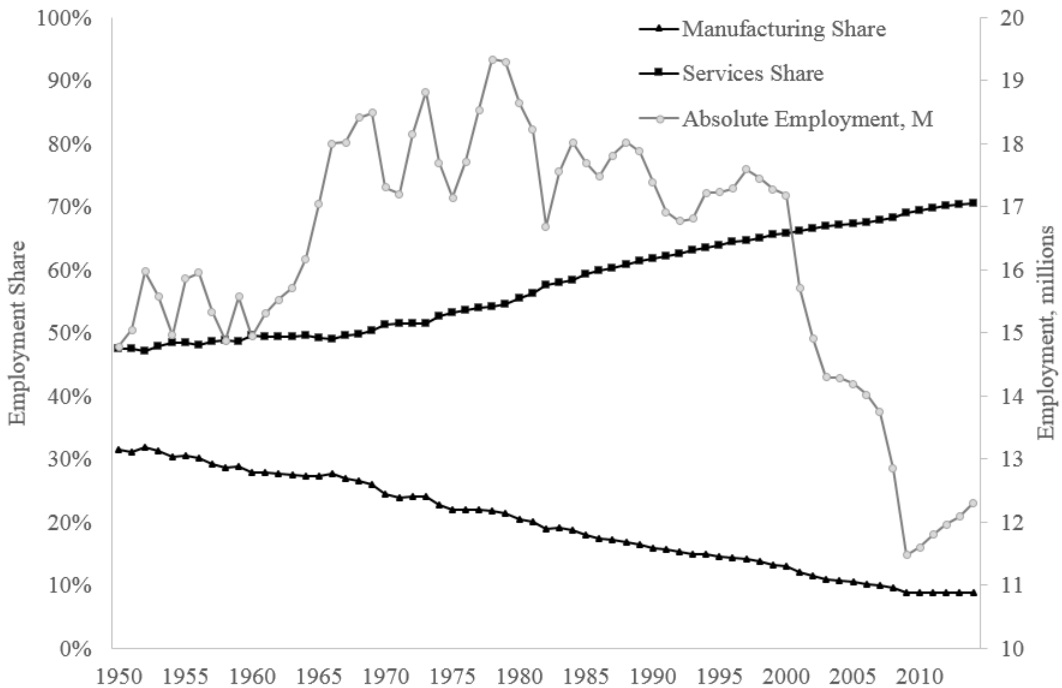
Chapter 3

Trade, Entry and Structural Transformation

3.1 Introduction

Structural transformation refers to the shift of production factors across economic sectors. Although this topic has been studied for decades, existing theories run into trouble in explaining the recent accelerated decline of manufacturing employment in many developed economies. Meanwhile, a growing empirical literature has emerged, documenting the close relationship between structural transformation and international trade during the same period. This paper adds to the existing theories of structural transformation by linking it with the reallocation forces of international trade liberalization. In particular, using an extended version of the Melitz (2003) model with multiple sectors, structural transformation arises from the interactions among trade liberalization, selective market entry, and skill-biased technology, in a way that is consistent with the evidence from the sharp decline of the U.S. manufacturing employment since 2000.

Like other developed countries, the share of manufacturing employment in the U.S. has



Source: Current Employment Statistics of the Bureau of Labor Statistics.

Figure 3.1. US Manufacturing Employment, 1950-2014.

experienced a steady decline in the post war era, from over 30% in 1950 to less than 10% in 2012, as shown in Figure 3.1. Accompanying this decline is the reciprocal rise of services. The growth of manufacturing output, measured by real value added, exceeded that of total GDP, keeping the manufacturing share of the economy constant in price-adjusted terms. This observation has been well supported by the "relative productivity hypothesis", which posits faster growth in manufacturing productivity combined with low relative income and price elasticities, and the "non-homothetic preference hypothesis", which assumes a falling share of manufactured goods in total expenditure as income rises.

However, after 2000, absolute manufacturing employment nosedived, losing nearly a third of job opportunities within a decade. This sharp fall brought challenge to the traditional theories of structural transformation. First, productivity growth in manufacturing relative to other sectors had been noticeably slower since 2000, as shown in Table 3.1. Second, the share

	1987-2013	1987-2000	2001-2013
	annualized percentage change		
Output			
Total Nonfarm Business	2.84	3.79	2.00
Manufacturing	1.86	3.73	0.39
Labor Productivity			
Total Nonfarm Business	2.03	2.02	2.05
Manufacturing	3.19	3.69	2.64
Multifactor Productivity			
Total Nonfarm Business	0.94	0.84	1.09
Manufacturing	1.20	1.17	1.24

Source: Major Sector Productivity and Costs, the Bureau of Labor Statistics.

Table 3.1. Productivity Growth in U.S. Manufacturing, 1987-2013

of manufactured goods in total expenditure, which fell from 41% in 1987 to 36% in 2000, has been very stable since 2000. In fact, Buera and Kaboski (2009) showed that the combination of these two hypotheses cannot explain the sharp fall of manufacturing employment since 2000.

In the meantime, led by Pierce and Schott (2014), an emerging empirical literature substantiates the role of international trade in the decline of manufacturing employment. Using the Current Employment Statistics of the Bureau of Labor Statistics, I find two facts that confirm the existing evidences. First, in both manufacturing and services industries, changes in employment share are inversely correlated to changes in the degree of trade liberalization. More specifically, as an industry becomes more liberalized, measured by a higher ratio of trade volume to total output, its employment share is more likely to decline. Second, the share of high skill employment increases with the degree of trade liberalization. In other words, low-skill workers are more likely to be reallocated from the liberalizing industries to the less liberalized and non-liberalizing industries.

Although, factor reallocation is nothing new to trade theories, existing studies of trade and structural transformation rely on the forces of comparative advantage: trade liberalization reallocates factors to the sector of comparative advantage. However, the comparative advantage mechanism, whether due to technological difference or factor abundance, cannot explain the inverse relationship between employment share and trade liberalization. In addition, existing multi-sector extensions of heterogeneous firm models either do not accommodate labor reallocation across sectors, or do so through the conventional comparative advantage mechanism.

To bridge the gap, this paper presents an extended multi-sector Melitz (2003) model that features both within and across sector factor reallocations in a way that is consistent with the existing evidences. First, deepening trade liberalization in the manufacturing industries reallocates employment towards more productive firms within the industry, and forces the least productive firms in each industry to exist, destructing existing manufacturing jobs. Second, it decreases the relative ex-ante attractiveness of the manufacturing sector and makes it easier for entrants to survive in the services sector. By allowing entrants to endogenously choose their sector of entry, trade liberalization in manufacturing suppresses manufacturing job creation and hence reallocates labor to services. Third, by incorporating skill-biased technology into the model, the low-skill jobs become more likely to be reallocated, resulting in an increasing share of skilled labor employment in the liberalizing sector. Last but not least, consumers gain from trade due to improved manufacturing productivity and diversified choices of services.

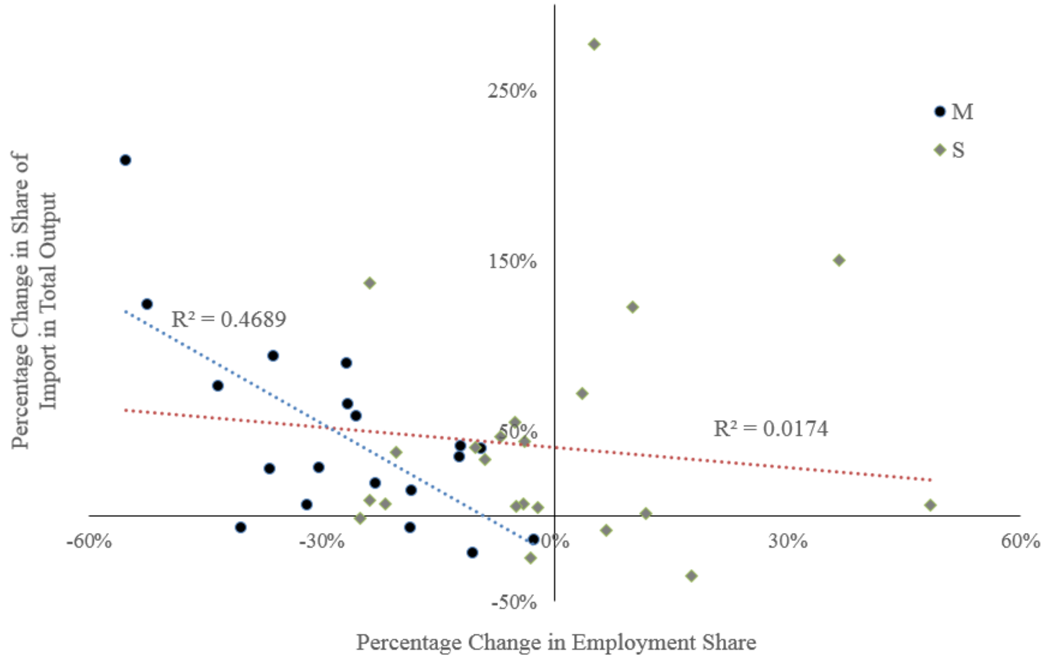
Before setting up the model, let me elaborate on the existing evidences and literature on trade and structural transformation.

3.1.1 Motivating Evidences

Various studies have established the impact of trade on labor allocation across sectors.[1] In an early survey, Kletzer (2003) documented six stylized facts about import-competing job loss. The first of them says that "import-related job loss is a sizeable share of U.S. manufacturing job loss, and a much smaller share of economy-wide job loss," suggesting the significant role of international trade in the decline of manufacturing sector. She also documented that the import-competing displaced manufacturing workers shared similar characteristics of workers displaced for other reasons, including older age and less education, and nearly 50% of re-employment of these displaced workers took place in other sectors with significant earnings loss. Using a longitudinal database of Brazilian individuals, Menezes-Filho and Muendler (2011) found similar job displacement patterns in Brazil after trade liberalization in 1990s. In addition, they pointed out that "neither exporters nor comparative-advantage sectors absorb trade-displaced labor," and "trade liberalization increases transition to services, unemployment, and out of the labor force," clearly indicating the deficiency of the comparative advantage mechanisms. In a recent study by Autor et al. (2013) on the impact of Chinese import competition on U.S. labor market between 1990 and 2007, it was found that "import competition explains one-quarter of the contemporaneous aggregate decline in U.S. manufacturing employment." At the firm level, Pierce and Schott (2014) in their study of the sharp drop in U.S. manufacturing employment since 2001, found that employment loss in manufacturing industries is "due to suppressed job creation, exaggerated job destruction and a substitution away from low-skill workers." The survey by Baily and Bosworth (2014) also recognizes the significant impact of trade in the decline of U.S. manufacturing.

Using the Occupational Employment Statistics (OES) from the Bureau of Labor Statistics

[1] Not all studies agree with this fact. For example, Baily and Lawrence (2004) and Mankiw and Swagel (2006) argue that international trade plays a small role in this phenomenon. Lawrence and Edwards (2013) point out trade deficit was already large in 2000, and job content of trade deficit in 2012 was similar to that in 2000, thus trade is only a minor factor.



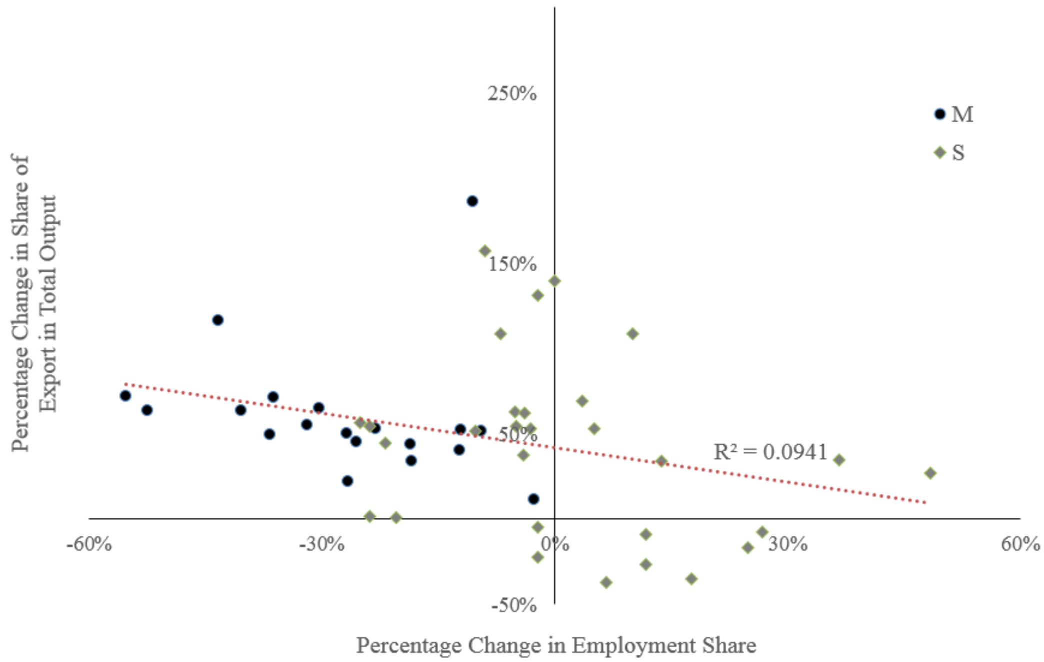
Source: Occupational Employment Statistics of the Bureau of Labor Statistics.

Figure 3.2. Changes in Industry Employment Shares and Import, 2002-2012.

and the industry level import and export data from the Bureau of Economic Analysis from 2002 to 2012, I find the following facts that are consistent with the existing evidence.

1. Most manufacturing industries lost employment. Those facing greater import penetration, measured by import over total output, experience greater loss (see Figure 3.2). On the other hand, about half of services industries expanded, but employment expansion is inversely related to the export expansion, measured by share of export over total output (see Figure 3.3). In general, increasing trade liberalization tends to reduce industry employment share (see Figure 3.4).

2. For both manufacturing and services industries, trade liberalization is positively correlated with changes in the share of high-skill employment. More specifically, both increase in import penetration and increase in export expansion tend to increase the



Source: Occupational Employment Statistics of the Bureau of Labor Statistics.

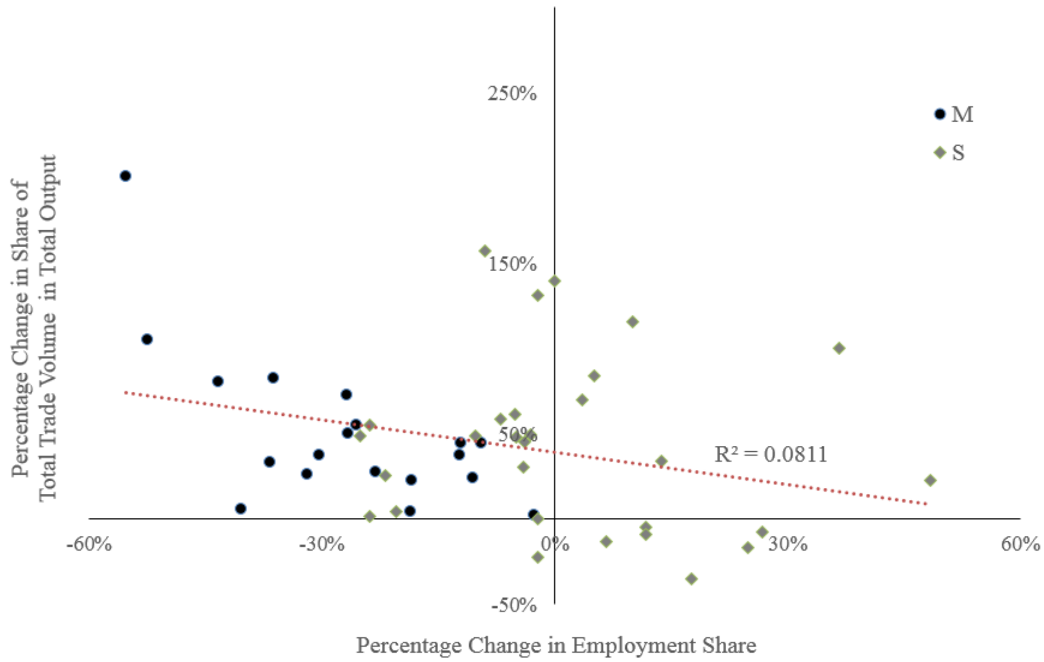
Figure 3.3. Changes in Industry Employment Shares and Export, 2002-2012.

share of high-skill employment (see Figure 3.5, 3.6, and 3.7).

3.1.2 Related Literature

The structural transformation literature stemmed from the early descriptive works by Fisher (1939), Clark (1957), Kuznets (1966), and Chenery and Syrquin (1976) on the decline of the agriculture and the rise of industry. Theories soon followed, proposing various mechanisms in closed economy settings.[2] Matsuyama (2009) was among the first to formalize the effect of international trade by arguing that relative improvements in manufacturing productivity

[2] Examples include non-homothetic preference, sector-biased productivity growth, changes in relative factor supply, evolution of market structures or demographics, and/or their combinations. See for example Matsuyama (1992), Caselli and II (2001), Kongsamut et al. (2001), Gollin et al. (2002), Hansen and Prescott (2002), Ngai and Pissarides (2007), Foellmi and Zweimller (2008), Acemoglu and Guerrieri (2008), Waugh and Lagakos (2009), Duarte and Restuccia (2010), Kuralbayeva and Stefanski (2013), Fajgelbaum and Redding (2014). Herrendorf et al. (2014) presented an excellent survey of this literature.



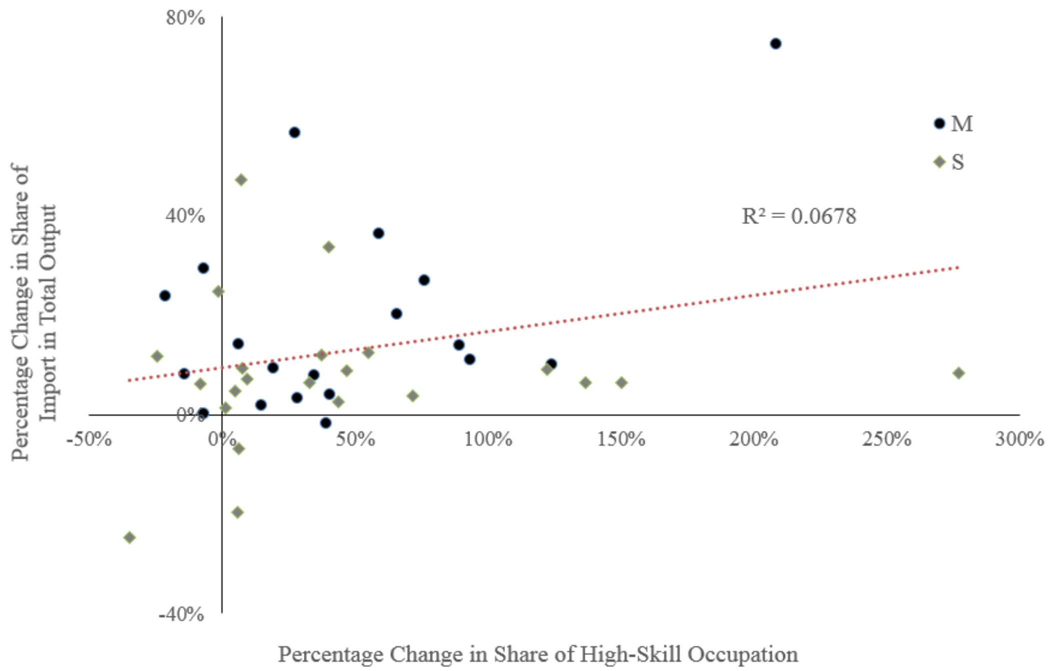
Source: Occupational Employment Statistics of the Bureau of Labor Statistics.

Figure 3.4. Changes in Industry Employment Shares and Total Trade, 2002-2012.

need not decrease manufacturing employment in a simple Ricardian model. Yi and Zhang (2010) took his idea into a multi-sector Eaton and Kortum (2002) model where exogenous productivity and trade friction shocks trigger interactions between comparative advantage and relative sectoral productivity growth, yielding interesting reallocation results.[3] However, these attempts are applications of the Ricardian comparative advantage, which has clear deficiencies shown by the recent evidences.

Apart from the Ricardian model, the classic Heckscher-Ohlin and many recent models like Bernard et al. (2003) and Bernard et al. (2007) can generate factor reallocation across sectors from different versions of comparative advantage. Whether due to differences in factor abundance or relative productivity, factors are always reallocated to the comparative advan-

[3]Additional examples of structural transformation in open economies include Echevarria (1997), Goldberg and Pavcnik (2007), Galor and Mountford (2008), Lurweg et al. (2010), Betts et al. (2013), etc.



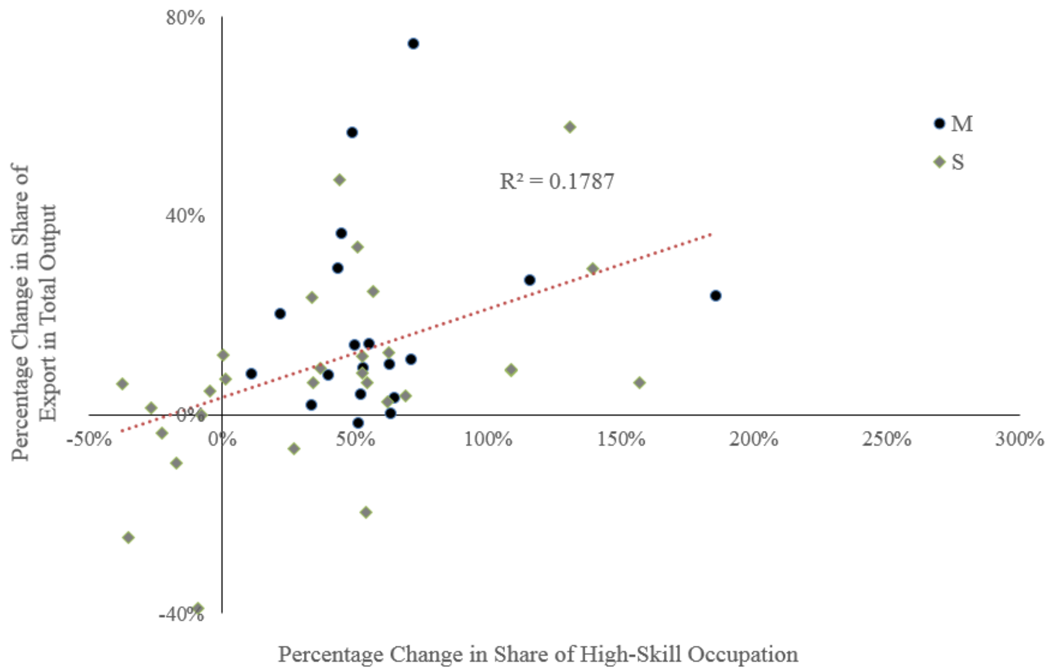
Source: Occupational Employment Statistics of the Bureau of Labor Statistics.

Figure 3.5. Changes in High-Skill Employment Shares and Import, 2002-2012.

tage sector. Net exporting sectors typically experience net job creation while net importing sectors endure net job destruction. As discussed before, such predictions are inconsistent with the fact that net job creation actually takes place in the less or non-liberalizing services industries rather than industries with comparative advantage. Led by Melitz (2003), recent advancements in trade and factor reallocation have stressed the importance of firm heterogeneity within a single industry or sector. However, multi-sector extensions of these models either do not accommodate structural transformation, or do so through the aforementioned mechanisms of comparative advantage.[4]

Another branch of the literature studies the dynamics and frictions related to the job turnovers ensued from trade liberalization. Recent examples include Dix-Carneiro (2010), Artuc et al. (2010), Helpman et al. (2010) and Coar et al. (2011). These papers primarily

[4]See for instance Balistreri et al. (2011) and Eaton et al. (2011).

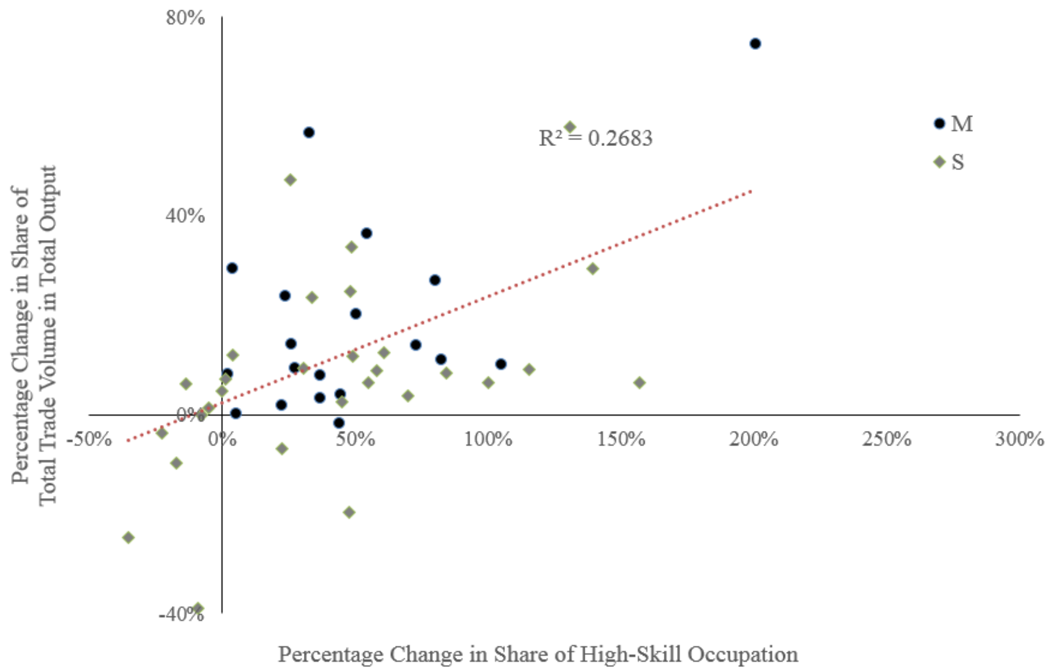


Source: Occupational Employment Statistics of the Bureau of Labor Statistics.

Figure 3.6. Changes in High-Skill Employment Shares and Export, 2002-2012.

focus on the welfare implications of labor market failures, which can potentially erode the gains to trade. The sources of job turnovers are similar to those already mentioned.

This paper differs from the existing literature by introducing a new mechanism for trade to influence structural transformation. Inspired by the reallocation forces in heterogeneous firm models, the new mechanism works without any form of comparative advantage, and is able to generate reallocation patterns consistent with the facts observed both within and across sectors. The basic model setup is most similar to Segerstrom and Sugita (2013) and Bernard et al. (2007). The former studied unilateral liberalization in a symmetric two-sector Melitz model while the latter incorporated factor intensity differences across sectors and factor abundance differences across countries into an otherwise standard two-sector Melitz model. Structural transformation can arise in these models from asymmetric trade liberalization across countries and the typical Heckscher-Ohlin mechanism. But neither is the emphasis of



Source: Occupational Employment Statistics of the Bureau of Labor Statistics.

Figure 3.7. Changes in High-Skill Employment Shares and Total Trade, 2002-2012.

my model. Instead, I will focus the effect of selective entry inspired by Arkolakis et al. (2013) in which entrants endogenously selects their sector of entry to maximize expected payoffs. Their decisions respond to the differences in the degree of trade liberalization across sectors. Coupled with the skill-biased technology from Burstein and Vogel (2012), the model is able to address the facts discussed in section 3.1.1.

The rest of the paper is organized as follows. Section 2 describes the basic model. Section 3 discusses the effect of selective entry. Section 4 discusses the effect of skill-biased technology. The extended model is numerically implemented in Section 5 for counterfactual experiments. Section 6 concludes.

3.2 The Basic Model

The basic model is a simple two-sector extension of the Melitz (2003) model. To mute the well-understood comparative advantage mechanism for factor reallocation, I assume symmetry across countries.

3.2.1 Model Setup

Consider a world consists of two symmetric but geographically separated economies, labelled by H and F. Each economy is made up of two sectors, manufacturing and services, indexed by $k \in \{M, S\}$. Labor is the only factor of production, the endowment of which is exogenously fixed at L in each economy. Wage is taken as the numeraire and normalized to unity. To simplify notations, the country index is omitted.

In each economy, the aggregate expenditures are allocated across the two sectors according to the following Cobb-Douglas demand function:

$$Q = Q_M^{\alpha_M} Q_S^{\alpha_S}, \tag{3.1}$$

where $\alpha_M \in (0, 1)$ and $\alpha_S = 1 - \alpha_M$. Within each sector, there is monopolistic competition over a continuum of varieties Ω_k. Consumers ration their expenditures over these varieties according to a constant-elasticity-of-substitution demand function

$$Q_k = \left[\int_{\Omega_k} q_k(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}, \tag{3.2}$$

for each $k \in \{M, S\}$. $\sigma > 1$ is the elasticity of substitution across different varieties.

A firm in sector k is defined as the producer of a single variety $\omega \in \Omega_k$. To enter the market, an entrant must pay a one-time entry cost f_E in labor for a random draw of its type z_k, which can be interpreted as the firm's idiosyncratic productivity. I assume that z_k

follows a Pareto distribution with cumulative distribution function

$$G_k(z_k) = 1 - \left(\frac{T}{z_k}\right)^{\theta} \tag{3.3}$$

defined over its support $z_k \geq T$. The parameters $T > 0$ and $\theta > \sigma - 1$ determine the location and dispersion of the distribution respectively. Production also requires a per-period fixed cost f_P in labor. The unit cost function of a type z_k firm is assumed to be

$$c_k(z_k) = z_k^{-1}. \tag{3.4}$$

All producing firms have the option to export. Doing so requires a per-period fixed cost f_X in labor and sector-specific ad-valorem trade cost $\tau_k \geq 1$. I assume that these costs satisfy $\tau_k^{\sigma-1} f_X > f_P$ to ensure clear partition of the exporters from the non-exporters. In addition, because services are typically consumed while being produced, and hence more difficult to store and transport, I assume that trade is costlier for S varieties, i.e.

$$\tau_M < \tau_S.$$

Last but not least, all incumbent firms face an exogenous probability δ to exit the market. In short, the two sectors may only differ in their α_k and τ_k in the basic model.

A noteworthy assumption important to the determination of the labor allocation across sectors is the free *independent entry*. Independence refers to the fact that entry is a sector-specific decision and independent of any conditions in the other sector. Entrants enter into their predetermined sector whenever it is potentially profitable to do so. Free entry implies that the sectoral value of entry, defined as the ex-ante expected profits of entrants, is zero. Modification to this assumption has important implications on labor reallocation, which will be discussed in section 3.3.

3.2.2 Labor Allocation in the Basic Model

The solution to the basic model is trivial when both economies are in autarky. The sectoral labor allocation can be easily deducted from the market clearing conditions. The aggregate expenditures on sector k, denoted by X_k, must equal the sectoral revenue R_k, which in turn must equal the sectoral labor income L_k, because all costs are denominated in labor and there are no aggregate profits due to free independent entry. The autarky share of labor l_k^A employed by sector k can be computed by

$$l_k^A = \frac{L_k}{L} = \frac{R_k}{L} = \frac{X_k}{L} = \frac{\alpha_k L}{L} = \alpha_k. \tag{3.5}$$

These equalities will hold as long as all costs are denominated in labor and entry is independent across sectors. In particular, if the trade cost τ_k is the standard iceberg cost and symmetric across economies, the sectoral employment will be invariant to any trade liberalization. The reallocation effect of trade only works within each sector as in the standard Melitz (2003) model, forcing the less productive firms to exit and moving labor to the more productive exporters. Therefore, structural transformation is muted in the basic setup. Before introducing modifications that can trigger structural transformation, let me first discuss the effect of alternative assumptions of τ_k.

3.2.3 The Role of Trade Costs

An easy way to break the ties in equation 3.5 is to distinguish different types of trade costs. If τ_k incorporates a component that is not denominated in labor, structural transformation can take place. To illustrate this effect, suppose the ad-valorem trade cost of sector k can be decomposed into two components:

$$\tau_k = t_k s_k, \tag{3.6}$$

where $s_k \geq 1$ is the standard iceberg component so that s_k units of products must be shipped for 1 unit to be delivered, and $t_k \geq 1$ is the non-iceberg component which I assume is denominated in the final good.[5] It can be shown that the equilibrium labor allocation across sectors can be determined by

$$l_k = \frac{L_k}{L} = \frac{\tilde{\alpha_k}}{\tilde{\alpha_M} + \tilde{\alpha_S}}, \tag{3.7}$$

where

$$\tilde{\alpha_k} = \alpha_k \left[\frac{1}{\sigma} + \left(\frac{1 + \frac{f_X}{f_P}^{\frac{\theta-\sigma+1}{1-\sigma}} \tau_k^{-\theta} t_k^{-1}}{1 + \frac{f_X}{f_P}^{\frac{\theta-\sigma+1}{1-\sigma}} \tau_k^{-\theta}} \right) \frac{\sigma - 1}{\sigma} \right]. \tag{3.8}$$

When $t_k = 1$, equation 3.8 becomes $\tilde{\alpha_k} = \alpha_k$, and thus $l_k = l_k^A$. In other words, trade liberalization through reduction in the iceberg trade cost has no effect on the sectoral employment share in the basic model. On the other hand, if $s_k = 1$, or equivalently $\tau_k = t_k$, i.e. exporters need not ship extra units to ensure delivery, but must bare extra surcharges over shipment value, it is easy to verify that $l_k \leq l_k^A$ given $\tau_M < \tau_S$, with equality only if $t_M = 1$. Intuitively, if the trade costs are paid with final goods which incorporate services components like shipping and freight, instead of "burning" more goods which requires additional labor to produce, the manufacturing employment share will decrease. The magnitude of this decrease depends on the total amount of non-iceberg trade costs paid. When the sector first opens up to trade, the increase in the trade volume will cause the total amount of t_k paid to initially increase. Further trade liberalization will result in a smaller share of manufacturing employment. However, after t_M reaches a certain threshold, decrease in t_k begins to dominate the increase in the trade volume, and the share of manufacturing employment will begin to rise, until $l_k = l_k^A$ when the non-iceberg trade cost is free.

Another effect of trade costs on structural transformation is through unilateral trade

[5] One may think of t_k as tariffs and other surcharges over the value of the shipment.

liberalization, i.e. to allow for asymmetric trade costs between trade partners. This scenario is discussed in details by Segerstrom and Sugita (2013), who showed that if $\tau_{M,HF} > \tau_{M,FH}$, or H becomes more liberalized in sector M such that it is cheaper for F's manufacturers to sell in H than H's manufacturers to sell in F, then labor in H will be reallocated from M to S.[6]

Since the effect of trade costs is orthogonal to other assumptions in the model, I will assume that τ_k is denominated in labor and symmetric across countries in the rest of this paper, and focus on the effects of selective entry and skill-biased technology.

3.3 The Effect of Selective Entry

As discussed in section 3.2, free *independent entry* considers entry a sector-specific decision, hence isolates the equilibrium outcomes of the two sectors. In particular, labor reallocation is strong within each sector, but absent across sectors. In this section, I will introduce free *selective entry*, an alternative entry assumption under which entry becomes an economy-wide decision, and discuss its implications on structural transformation.

More specifically, suppose that after paying the entry cost f_E, entrants randomly draw their $z = (z_M, z_S)$ from a joint distribution function $G(z_M, z_S)$, and then choose to produce in the more profitable sector or exit if neither sector is profitable. Immediately, the two sectoral free entry conditions are combined into one economy-wide free entry condition, which only forbids positive value of entry in the entire economy, but not in each sector.

In contrast to independent entry, which only differentiates entrants by productivities in their destined sector, selective entry further differentiates them by their potential competence

[6]Another interesting implication of this assumption shown by Segerstrom and Sugita (2013) is that unilateral trade liberalization in manufacturing will indefinitely increase the average idiosyncratic productivity in the non-liberalizing services sector, but may or may not increase that in the liberalizing manufacturing sector, contradicting the empirical evidences in Trefler (2004).

in other sectors. As entrants are aware of their potential opportunities in different sectors, they seek to devote their efforts to the sector that brings the most profits. In the current model where they have perfect information of their capabilities and the market, their entry decisions can be simplified to choosing the sector with higher profits after observing their productivity draws.

Before discussing the effect of selective entry on structural transformation, let me first characterize the equilibrium of the modified model with the help of two additional assumptions. First, I assume $G(z_M, z_S)$ is a bivariate Pareto distribution with the following cumulative distribution function

$$G(z_M, z_S) = 1 - \left[\left(\frac{T}{z_M} \right)^{\frac{\theta}{1-\rho}} + \left(\frac{T}{z_S} \right)^{\frac{\theta}{1-\rho}} - \left(\frac{T}{z_M} \frac{T}{z_S} \right)^{\frac{\theta}{1-\rho}} \right]^{1-\rho} \tag{3.9}$$

and support $z_k \geq T$.[7] The marginal distribution of z_k is defined in equation 3.3. The dependence structure is solely captured by $\rho \in [0, 1)$, which can be thought of as the correlation coefficients between z_M and z_S. When $\rho = 0$, $G(z_M, z_S) = G_M(z_M)G_S(z_S)$, z_M and z_S are independent. When ρ approaches 1, z_M and z_S approach perfect correlation. This choice of this functional form allows intuitive characterization of the dependence structure and convenient numerical implementation. The results in the following sections are not particular to this choice.

Second, because entrants are no longer sector-specific under selective entry, to allocate the entry cost to each sector, I further assume that f_E is counted as M employment if the entrant is more profitable in M, even if profits are negative. This assumption essentially ties entry costs to the entrants' destination sector.[8] An alternative assumption is to denominate

[7]This functional form is modified from the multivariate Pareto distribution used in Arkolakis et al. (2013). It is equivalent to applying the Archimedean copula 4.2.6 in Nelson (2006) to the Pareto marginals defined in equation 3.3.

[8]If entry costs are allocated such that there is no sectoral net value of entry, then there will be no structural transformation as discussed in section 3.2.2. However, such an allocation would count the entry

entry cost in final goods, which will produce similar results.

3.3.1 Equilibrium Conditions under Selective Entry

I follow Melitz (2003) to solve the model. By symmetry, it suffices to solve the model for only one of economies.

First, the fixed cost f_P of production induces a cutoff productivity z_k^* in each sector, below which firms cannot profit at all. Likewise, the fixed export cost f_X leads to another cutoff $z_{k,X}^*$, below which firms cannot profit from exporting. These cutoff productivities can be defined from the zero profit conditions in the domestic and export markets, which yield

$$z_k^* = \left(\frac{\sigma f_P}{\alpha_k L}\right)^{\frac{1}{\sigma-1}} \frac{\hat{\sigma}}{P_k} \quad \text{and} \quad z_{k,X}^* = \left(\frac{f_X}{f_P}\right)^{\frac{1}{\sigma-1}} \tau_k z_k^*, \tag{3.10}$$

where $\hat{\sigma} = \frac{\sigma}{\sigma-1}$ is the constant mark-up brought by the CES demand function, and P_k is the equilibrium price index of sector k.

Second, entrants decide which sector to enter by comparing their profits in each sector. To characterize their decisions, I define the following equi-profit line given that $\tau_M < \tau_S$:

$$\hat{z}_S(z_M) = \begin{cases} \hat{\alpha} \frac{P_M}{P_S} z_M & \text{if } z_M \in [T, z_{M,X}^*), \\ \frac{\hat{\alpha}}{\tau_M} \frac{P_M}{P_S} \left[(\hat{\tau}_M z_M)^{\sigma-1} - (z_{M,X}^*)^{\sigma-1} \right]^{\frac{1}{\sigma-1}} & \text{if } z_M \in [z_{M,X}^*, \frac{\hat{\tau}_S}{\hat{\tau}_M} z_{M,X}^*), \\ \hat{\alpha} \frac{P_M}{P_S} \frac{\hat{\tau}_M}{\hat{\tau}_S} \frac{\tau_S}{\tau_M} z_M & \text{if } z_M \in [\frac{\hat{\tau}_S}{\hat{\tau}_M} z_{M,X}^*, \infty), \end{cases} \tag{3.11}$$

where $\hat{\alpha} = (\frac{\alpha_M}{\alpha_S})^{\frac{1}{\sigma-1}}$ and $\hat{\tau}_k = \left(\tau_k^{\sigma-1} + 1\right)^{\frac{1}{\sigma-1}}$ are constants. Firms with type $z = (z_M, z_S)$ such that $z_S = \hat{z}_S(z_M)$ will have equal profits in both sectors regardless of their export status, and are thus indifferent between entering either sector. Those with $z_S < \hat{z}_S(z_M)$ will

cost of a firm that joins or would join the services sector as manufacturing employment, which is rather counter-intuitive.

be more profitable in M, while those with $z_S > \hat{z}_S(z_M)$ will prefer to produce in S.

Equations 3.10 and 3.11 partition the entire set of entrant types into four disjoint sets: the successful entrants in M and S, denoted by $\mathbb{Z}_M$ and $\mathbb{Z}_S$, and the unsuccessful manufacturers and services entrants that exit immediately after entry, denoted by $\mathbb{Z}_M^{null}$ and $\mathbb{Z}_S^{null}$, where

$$\begin{aligned} \mathbb{Z}_M &:= \{z \in \mathbb{R}^2 | z_M^* \leq z_M \text{ and } T \leq z_S < \hat{z}_S(z_M)\}, \\ \mathbb{Z}_S &:= \{z \in \mathbb{R}^2 | z_S^* \leq z_S \text{ and } T \leq z_M < \hat{z}_S^{-1}(z_S)\}, \\ \mathbb{Z}_M^{null} &:= \{z \in \mathbb{R}^2 | T^{\frac{1}{\theta}} \leq z_M < z_M^* \text{ and } T \leq z_S < \hat{z}_S(z_M)\}, \\ \mathbb{Z}_S^{null} &:= \{z \in \mathbb{R}^2 | T^{\frac{1}{\theta}} \leq z_S < z_S^* \text{ and } T \leq z_M < \hat{z}_S^{-1}(z_S)\}. \end{aligned} \tag{3.12}$$

In addition, the set of exporters in each sector are denoted by $\mathbb{Z}_M^X$ and $\mathbb{Z}_S^X$, where

$$\begin{aligned} \mathbb{Z}_M^X &:= \{z \in \mathbb{R}^2 | z_{M,X}^* \leq z_M \text{ and } T \leq z_S < \hat{z}_S(z_M)\} \subseteq \mathbb{Z}_M, \\ \mathbb{Z}_S^X &:= \{z \in \mathbb{R}^2 | z_{S,X}^* \leq z_S \text{ and } T \leq z_M < \hat{z}_S^{-1}(z_S)\} \subseteq \mathbb{Z}_S. \end{aligned} \tag{3.13}$$

Let N_E be the equilibrium mass of entrants in the economy. The sectoral price index is defined as

$$P_k = \hat{\sigma} \left[\frac{N_E}{\delta} \left(\iint_{\mathbb{Z}_k} z_k^{\sigma-1} dG + \tau_k^{1-\sigma} \iint_{\mathbb{Z}_k^X} z_k^{\sigma-1} dG \right) \right]^{\frac{1}{1-\sigma}}. \tag{3.14}$$

Then, the price ratio in the equi-profit line can be computed by

$$\left(\frac{P_M}{P_S} \right)^{1-\sigma} = \frac{\iint_{\mathbb{Z}_M} z_M^{\sigma-1} dG + \tau_M^{1-\sigma} \iint_{\mathbb{Z}_M^X} z_M^{\sigma-1} dG}{\iint_{\mathbb{Z}_S} z_S^{\sigma-1} dG + \tau_S^{1-\sigma} \iint_{\mathbb{Z}_S^X} z_S^{\sigma-1} dG}. \tag{3.15}$$

Equations 3.10 to 3.15 together define $\frac{P_M}{P_S}$ as an implicit function of z_M^*. In particular, it is the unique fixed point to equations 3.15.[9] Therefore, z_M^* is sufficient to characterize the

[9] The left-hand side is continuous and strictly decreasing in $\frac{P_M}{P_S}$, which approaches ∞ as $\frac{P_M}{P_S} \to 0$ and 0 as $\frac{P_M}{P_S} \to \infty$, whereas the right-hand side is continuous and strictly increasing in $\frac{P_M}{P_S}$ with the inverse limits. Therefore, the fixed point $\frac{P_M}{P_S}$ exists and is unique given z_M^*.

equi-profit line, the cutoff productivities in both sectors, the partition sets of entrants, and therefore the entry decisions of all entrants.

To solve for the equilibrium z_M^*, I make use of the free entry condition, which states that the net value of entry is zero in the economy. Note that the profits of a type $z = (z_M, z_S)$ firm is the maximum of its sectoral profits, i.e.

$$\pi(z) = \max\left\{\pi_M(z_M), \pi_S(z_S), 0\right\}, \tag{3.16}$$

where

$$\pi_k(z_k) = \mathbb{1}\{z \in \mathbb{Z}_k\}\left[\left(\frac{z_k}{z_k^*}\right)^{\sigma-1} - 1\right] f_P + \mathbb{1}\{z \in \mathbb{Z}_k^X\}\left[\left(\frac{z_k}{z_{k,X}^*}\right)^{\sigma-1} - 1\right] f_X. \tag{3.17}$$

The free entry condition can thus be written as

$$\frac{1}{\delta}\left[\iint_{\mathbb{Z}_M} \pi_M(z_M)\, dG + \iint_{\mathbb{Z}_S} \pi_S(z_S)\, dG\right] = f_E. \tag{3.18}$$

The left-hand size is a strictly decreasing function of z_M^*, which can only cut the right-hand size from above once. Therefore, the equilibrium z_M^* exists and is unique under regulating conditions on the model parameters.

To complete the equilibrium characterization, I solve for the equilibrium mass of entrants N_E from the labor market clearing condition:

$$L = \frac{L}{\hat{\sigma}} + \iint_{\mathbb{Z}_M + \mathbb{Z}_S} \frac{N_E}{\delta} f_P\, dG + \iint_{\mathbb{Z}_M^X + \mathbb{Z}_S^X} \frac{N_E}{\delta} f_X\, dG + N_E f_E. \tag{3.19}$$

The left-hand side is the total labor supply. The right-hand side is the total labor demand, which is the sum of the total variable production costs, fixed production costs, fixed export costs, and entry costs. Equipped with the unique equilibrium of the modified model, let me move on to discuss the effect of selective entry on structural transformation by comparing the equilibrium outcomes before and after reduction in trade costs.

3.3.2 Selective Entry and Structural Transformation

As discussed before, selective entry allows positive value of entry in a single sector. Let Ψ_k be the aggregate sectoral value of entry, which also equals the aggregate sectoral profits,

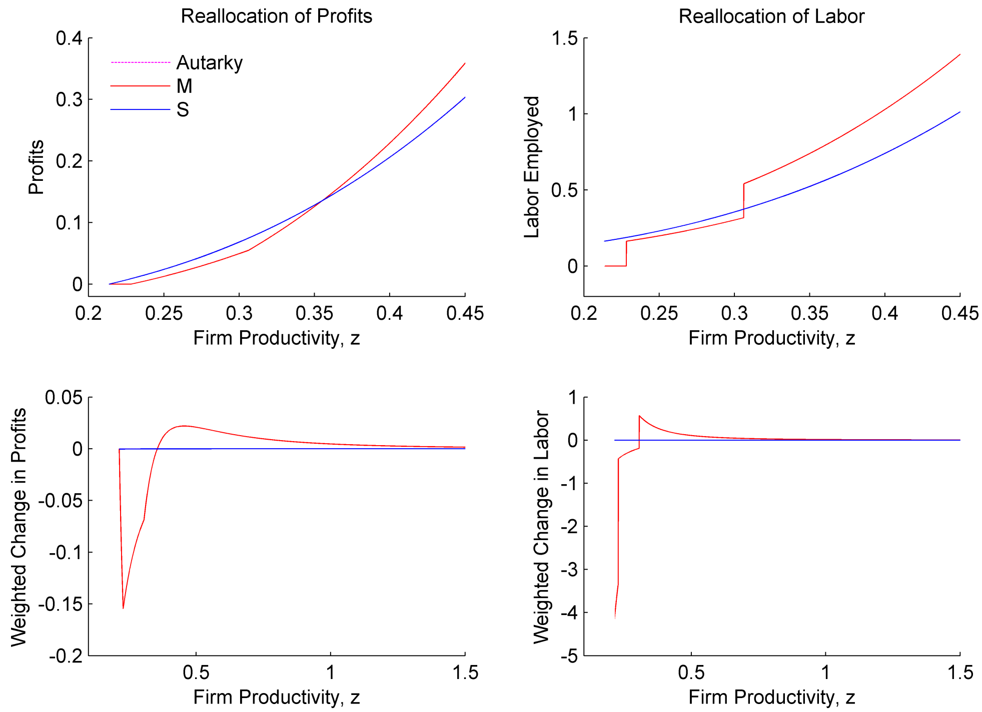
$$\Psi_k = \frac{\alpha_k L}{\sigma} - \iint_{\mathbb{Z}_k} \frac{N_E}{\delta} f_P \, dG - \iint_{\mathbb{Z}_k^X} \frac{N_E}{\delta} f_X \, dG - \iint_{\mathbb{Z}_k + \mathbb{Z}_k^{null}} N_E f_E \, dG. \tag{3.20}$$

Hence, the total sectoral employment, which also equals the total costs, can be written as the difference between sectoral revenue R_k and Ψ_k,

$$L_k = R_k - \Psi_k = \alpha_k L - \Psi_k. \tag{3.21}$$

Apparently, trade liberalization can trigger structural transformation through Ψ_k. In particular, if reduction in trade costs of sector M can increase Ψ_M, i.e. $\frac{\partial \Psi_M}{\partial \tau_M} > 0$, total manufacturing employment will decrease.

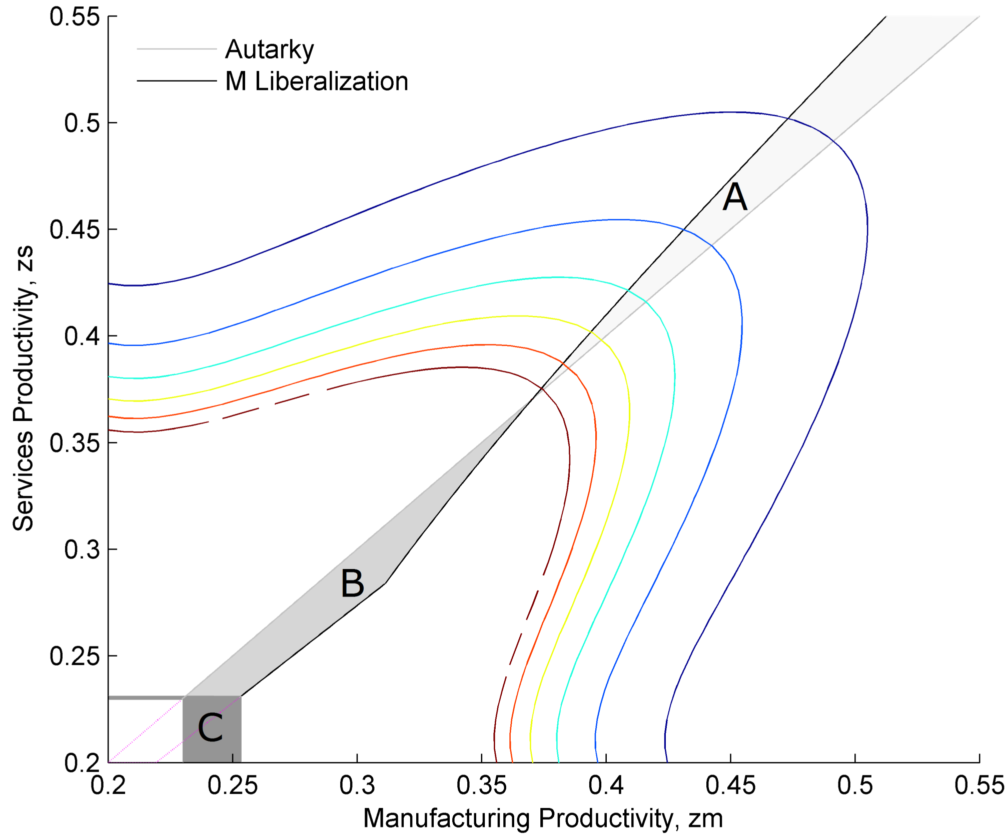
To derive the above result, start with total differentiation of equation 3.18, which yields $\frac{\partial z_M}{\partial \tau_M} > 0$. The definition of equi-profit line $\hat{z}_S(z_M)$ implies $\frac{\partial z_S}{\partial \tau_M} > 0$. Note that $\hat{z}_S(z_M)$ is continuous but not differentiable at $z_M = z^*_{M,X}$ and $\hat{z}_S(z_M) = z^*_{S,X}$, thus requiring aggregating piecewise derivatives at each partition. By equation 3.10, price indices in both sectors must decrease, $\frac{\partial P_M}{\partial \tau_M} < 0$ and $\frac{\partial z_S}{\partial \tau_M} < 0$. Combining equations 3.18 and 3.19, it is straight forward to show that the mass of entrants increases $\frac{\partial N_E}{\partial \tau_M} > 0$. Finally, total differentiation of Ψ_k with respect to τ_M will produce the desired $\frac{\partial \Psi_M}{\partial \tau_M} > 0$. As the kinks in the equi-profit line considerably complicate the derivatives, Section 3.5 presents intuitive illustrations of the same results.



Remark: The top panel shows firms' profits and employment in both sectors after reduction in τ_M when entry is independent. The bottom panel shows the associated change in firms' profits and employment, weighted by the Pareto densities of each z_k.

Figure 3.8. Reallocation of Profits and Labor under Independent Entry

The structural transformation above can be understood by comparing the equilibrium outcomes under different entry assumptions. First, when entry is independent, reduction in τ_M removes jobs in the less productive domestic manufacturers and creates jobs in the more productive exporters, but does not change the equilibrium mass of manufacturing entrants. The market clearing conditions in equations 3.5 hold in this case, so the destruction of jobs in the less productive firms is exactly offset by the creation of jobs in the exporters. Figure 3.8 plots the reallocation of profits and labor across firms in both sectors after reduction in τ_M. Clearly, the equilibrium employment in S is unaffected, and the density-weighted decrease in domestic manufacturers' employment shown in the bottom right panel is reallocated towards the exporters in M.



Remark: The solid black line is the equi-profit line after reduction in τ_M. Firms with productivity draws above the line will enter into S, while those below the line will enter into M. For comparison, the grey line is the autarky equi-profit line. The contour lines represent the density of the joint distribution. The area labelled A contains the S entrants who will enter into M after t_M reduction, area B contains the M entrants that move into S, and area C are the exiting manufacturing and services firms.

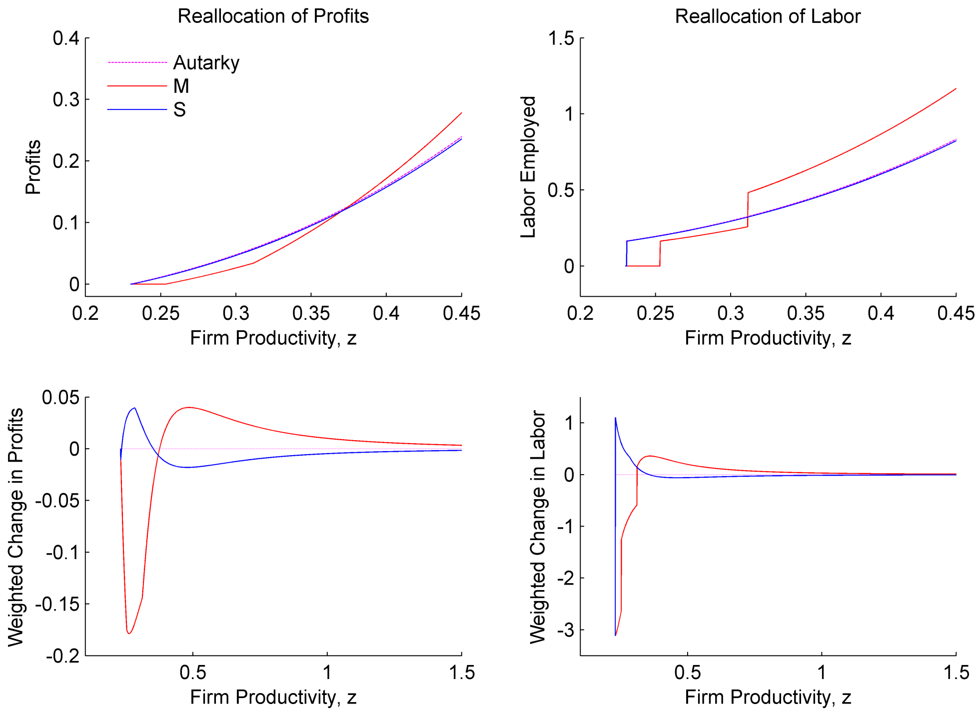
Figure 3.9. The Equi-Profit Line and Trade Liberalization in Manufacturing Sector

This Melitz mechanism of labor reallocation within M is still present under selective entry. However, the potential competence in the services sector possessed by different manufacturing entrants can affect the equilibrium mass of entrants in both sectors and the associated ex-post marginal densities, which in turn affect the equilibrium outcomes in both sectors. To see this, Figure 3.9 shows the change in the equi-profit line before and after reduction in τ_M. On the one hand, the profit growth of the more productive manufacturing exporters caused by the Melitz mechanism increases the relative attractiveness of the manufacturing sector among the services entrants with high potentials in M, therefore transforms the mass of entrants contained in area A from S to M. On the other hand, the profit decline among the domestic and less productive exporting manufacturers moves those with higher services potentials contained in area B to S. As a result, the new equi-profit line discourages the less productive entrants to join M but encourages the more productive ones, thereby tilting the ex-post marginal density of z_M towards the more productive firms. These changes imply two channels of structural transformation. First, job destruction among the less productive firms is exaggerated, while job creation among the more productive ones is enhanced. However, since the density of firms in area A is much thinner than that in area B, the enhanced creation is dominated by the exaggerated destruction when weighted by the tilted marginal density, yielding a net destruction of manufacturing jobs. Figure 3.10 shows the aforementioned reallocation of profits and labor under selective entry. In contrast to Figure 3.8, the equilibrium outcomes in S is also affected. In particular, more services jobs are created by the encouraged entry of less productive firms. Second, the tilted equi-profit line also increases the ex-post probability of entry into S, further suppressing job creation in the entry segment of M and enhancing job creation in the entry segment of S. The combined effect of these two channels leads the decrease in the employment share of M.

Besides structural transformation, selective entry also has important welfare implications. Since wage is chosen as the numeraire, the welfare of the economy can be measured by the inverse of the total price index,

$$P^{-1} = \left(\frac{P_M}{\alpha_M}\right)^{-\alpha_M} \left(\frac{P_S}{\alpha_S}\right)^{-\alpha_S}. \tag{3.22}$$

Let $N_{k,T}$ be the total mass of varieties available in sector k, including all imported varieties,



Remark: The top panel shows firms' profits and employment in both sectors after reduction in τ_M under the selective entry assumption. The bottom panel shows the associated change in firms' profits and employment, weighted by the ex-post marginal densities of z_M and z_S.

Figure 3.10. Reallocation of Profits and Labor under Selective Entry

and $\tilde{z}_k$ be the average firm productivity in that sector, where

$$\begin{aligned} N_{k,T} &= \iint_{\mathbb{Z}_k} dG \frac{N_E}{\delta} + \iint_{\mathbb{Z}_k^X} dG \frac{N_E}{\delta}, \\ \tilde{z}_k &= \left[\frac{1}{N_{k,T}} \left(\iint_{\mathbb{Z}_k} z_k^{\sigma-1} dG \frac{N_E}{\delta} + \tau_k^{1-\sigma} \iint_{\mathbb{Z}_k^X} z_k^{\sigma-1} dG \frac{N_E}{\delta} \right) \right]^{\frac{1}{\sigma-1}}. \end{aligned} \tag{3.23}$$

Then the sectoral price index in equation 3.22 can be re-written as

$$P_k = \hat{\sigma} (N_{k,T})^{\frac{1}{1-\sigma}} \frac{1}{\tilde{z}_k}. \tag{3.24}$$

Thus, welfare is a decreasing function of P_k, which in turn is a decreasing function of both

$\tilde{z}_k$ and $N_{k,T}$. So consumers can gain from trade liberalization either through improvement in the average productivity, or expansion of the choice of varieties, or both.

The gains from trade under selective entry comes from the reduction of price in both sectors shown before. However, the reduction in each sector has different reasons. First, the increase in the entry cutoff productivity and the tilted equi-profit line favoring the more productive exporters together improve the average productivity in M. Although the mass of incumbent firm in M is reduced, limiting the number of M varieties, the productivity gain dominates, resulting in a cheaper P_M. The reduction in P_S is quite the opposite. Because the change to the equi-profit line increases the marginal density of less productive firms in S, average productivity in S can deteriorate. But the same change also brings a much larger mass of services varieties, therefore reduces P_S. Section 3.5 numerically illustrates the gains from trade under selective entry.

To sum up, selective entry provides an additional channel through which trade liberalization can affect structural transformation. By suppressing job creation in the entry segment and exaggerating job destruction in the less productive firms, trade liberalization reduces the employment share of the liberalizing sector, consistent with the first fact and other existing firm level and labor market evidences discussed in section 3.1.1. Under selective entry, consumers gain from deepening trade liberalization through improvement of the average productivities of the liberalizing sector and introduction of more varieties in other sectors.

In the next section, I will incorporate skill-biased technology to model the second fact in section 3.1.1, which states that the share of skilled labor employment increases with trade liberalization, and discuss its implications on structural transformation and welfare.

3.4 The Effect of Skill-biased Technology

It has been shown that workers displaced by trade liberalization are in general less skillful and educated. It is also well known that trade liberalization withdraws resources from the less productive firms, and forces the least productive firms to exit. To link these disparities, I incorporate a simple form of complementarity between labor skills and firm productivities introduced by Burstein and Vogel (2012) into the basic model. As a result, more productive firms are also more skill intensive. Trade liberalization not only favors the more productive firms, but also benefits the skilled labor.

Consider two types of labor: skilled and unskilled. The total supply of each type is fixed at S and L respectively, with $S + L = 1$. The unit cost function of a type z_k firm is assumed to be

$$c_k(z_k, w_S, w_L) = \left[\beta_k \left(\frac{w_S}{z_k^{1+\gamma}}\right)^{1-\eta} + (1-\beta_k)\left(\frac{w_L}{z_k^{1-\gamma}}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}},$$

where $0 \leq \beta_k \leq 1$ and $0 \leq \gamma \leq 1$ determine the skill intensities, $\eta > 0$ governs the elasticity of substitution between the two skills, and w_S and w_L are the wage of skilled and unskilled labor.[10] This cost function has a few convenient features. First, it is strictly decreasing in z_k. Hence its inverse in z_k is well defined, which I denote as c_k^{-1}. Second, it is homogenous in w_L, so w_L can be taken as the numeraire without affecting equilibrium conditions. Denote the skill premium by w, then the cost function can be re-written as

$$c_k(z_k, w) = \left[\beta_k \left(\frac{w}{z_k^{1+\gamma}}\right)^{1-\eta} + (1-\beta_k)\left(\frac{1}{z_k^{1-\gamma}}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{3.25}$$

Third, the resulting ratio of skilled employment $S_k(z_k, w)$ to unskilled employment $L_k(z_k, w)$

[10]When $\eta = 1$, $c_k(z_k, w_S, w_L) = \left(\frac{w_S}{z_k^{1+\gamma}}\right)^{\beta_k} \left(\frac{w_L}{z_k^{1-\gamma}}\right)^{1-\beta_k}$.

as variable inputs depends on the firm's productivity z_k:

$$\frac{S_k(z_k, w)}{L_k(z_k, w)} = \frac{\beta_k}{1-\beta_k} z_k^{2\gamma(\eta-1)} w^{-\eta}. \tag{3.26}$$

If $2\gamma(\eta - 1) = 0$, technology is *Hicks neutral*, meaning that skill intensity is uniform across firms. If $2\gamma(\eta - 1) > 0$, technology is *skill-biased*, because the relative demand of skill labor increases with the firm's productivity. In this case, reduction in trade costs in a sector will reallocate factors from the less productive firms to the more productive firms, increasing the relative demand of skilled labor and raising the skill premium. Burstein and Vogel (2012) named this the *skill-biased technology mechanism*.

In this section, I assume that technology is skill-biased, i.e. $\gamma(\eta - 1) > 0$. For compositional purposes, I also assume that all fixed and entry costs are all denominated in unskilled labor L. Again, to mute the potential factor intensity based comparative advantage mechanism of factor reallocation, economies are assumed to be completely symmetric.

Before discussing the effect of skill-biased technology, let me first characterize the equilibrium conditions under different entry assumptions. Since the skill premium affects outcomes in both sectors, equations 3.5 no longer hold. Trade liberalization can trigger structural transformation through the skill-biased technology mechanism. However, it is more interesting to see how it interacts with selective entry.

3.4.1 Equilibrium Conditions with Skill-biased Technology

By symmetry, it suffices to describe the equilibrium for H. Since equation 3.25 lacks a closed form inverse, it is compositionally simple to work with the cost function.

3.4.1.1 The Case of Independent Entry

When entry is independent, the cost distribution G_k^c conditional on the skill premium can be derived from the firm's type distribution defined in equation 3.3 by

$$G_k^c(c|w) = \Pr\left[c_k(z_k, w) < c\right] = \Pr\left[z_k > c_k^{-1}(c, w)\right] = 1 - G_k\left(c_k^{-1}(c, w)\right), \tag{3.27}$$

with support $0 \leq c \leq \bar{c} = c_k(T, w)$.

Because of the fixed costs, each sector has a pair of cutoff costs $c_k^*(w)$ and $c_{k,X}^*(w)$ for production and exporting. Using the zero profit conditions, they can be written as

$$c_k^*(w) = \left(\frac{\sigma f_P}{\alpha_k X}\right)^{\frac{1}{1-\sigma}} \frac{P_k(w)}{\hat{\sigma}} \quad \text{and} \quad c_{k,X}^*(w) = \left(\frac{f_X}{f_P}\right)^{\frac{1}{1-\sigma}} \frac{c_k^*(w)}{\tau_k}, \tag{3.28}$$

where $X = wS + L$ is the aggregate expenditure in the economy, and the sectoral price index $P_k(w)$ satisfies

$$\left(\frac{P_k(w)}{\hat{\sigma}}\right)^{1-\sigma} = \frac{N_{E,k}(w)}{\delta}\left[\int_0^{c_k^*(w)} c_k(z_k, w)^{1-\sigma} + \int_0^{c_{k,X}^*(w)} (\tau_k c_k(z_k, w))^{1-\sigma}\right] dG_k^c(c|w). \tag{3.29}$$

Given the wage premium w, the equilibrium cutoff costs can be solved from the free entry condition of each sector:

$$\frac{1}{\delta}\left[\int_0^{c_k^*(w)} \left(\frac{c^{1-\sigma}}{c_k^*(w)^{1-\sigma}} - 1\right) f_P + \int_0^{c_{k,X}^*(w)} \left(\frac{c^{1-\sigma}}{c_{k,X}^*(w)^{1-\sigma}} - 1\right) f_X\right] dG_k^c(c|w) = f_E. \tag{3.30}$$

The left hand size of the above equation is strictly increasing in $c_k^*(w)$ and approaches 0 as $c_k^*(w) \to 0$. Hence, $c_k^*(w)$ exists and is unique under regulating conditions on the model parameters. Subsequently, the equilibrium mass of entrants $N_{E,k}(w)$ in each sector can be solved from equations 3.28, 3.29 and the value of $c_k^*(w)$ just obtained.

All the above equilibrium objects depend on the skill premium w, which can be solved from the labor market clearing conditions. Note that it is sufficient to use only one of the two conditions. For the skilled labor market, it is

$$S = \sum_{k=M,S} \left[\int_0^{c_k^*(w)} S_k(c_k, w) + \int_0^{c_{k,X}^*(w)} S_{k,X}(c_k, w) \right] dG_k^c(c|w), \tag{3.31}$$

where $S_k(c_k, w)$ and $S_{k,X}(c_k, w)$ are the skilled labor employed to supply domestic and export markets by firms with cost level equals to c_k:

$$\begin{aligned} S_k(c_k, w) &= \beta_k \left[c_k^{-1}(c_k, w) \right]^{(1+\gamma)(\eta-1)} \left[\frac{w}{c_k} \right]^{-\eta} [\hat{\sigma} c_k]^{-\sigma} (P_k)^{\sigma-1} \alpha_k X, \\ S_{k,X}(c_k, w) &= \tau_k^{1-\sigma} S_k(c_k, w). \end{aligned} \tag{3.32}$$

It can be shown that the total demand of skilled labor in equation 3.31 is downward sloping in w. Therefore, under regulating conditions, the model has a unique equilibrium characterized by equations 3.27 to 3.32.

3.4.1.2 The Case of Selective Entry

When there is selective entry, the costs distribution conditional on w can be written as

$$\begin{aligned} G^c(c_M, c_S|w) =& \Pr\left[c_M(z_M, w) < c_M,\ c_S(z_S, w) < c_S \right] \\ =& \Pr\left[z_M > c_M^{-1}(c_M, w),\ z_S > c_S^{-1}(c_S, w) \right] \\ =& 1 - G(c_M^{-1}(c_M, w), \bar{c}) - G(\bar{c}, c_S^{-1}(c_S, w)) + G(c_M^{-1}(c_M, w), c_S^{-1}(c_S, w)), \end{aligned} \tag{3.33}$$

where G is defined in equation 3.9. The support of this distribution is $(0, \bar{c}] \times (0, \bar{c}]$.

The equilibrium conditions in this case mimic those in section 3.3.1. The production cutoff cost $c_k^*(w)$ and export cutoff cost $c_{k,X}^*(w)$ in each sector are the same as in equation

3.28. The equi-profit line in terms of the cost function can be written as

$$\hat{c}_S(c_M,w) = \begin{cases} \frac{1}{\hat{\alpha}}\frac{P_S(w)}{P_M(w)}c_M & \text{if } c_M \in (c^*_{M,X}(w), c^*_M(w)], \\ \frac{\tau_M}{\hat{\alpha}}\frac{P_S(w)}{P_M(w)}\left[\left(\frac{c_M}{\hat{\tau}_M}\right)^{1-\sigma} - c^*_{M,X}(w)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} & \text{if } c_M \in (\frac{\hat{\tau}_M}{\hat{\tau}_S}c^*_{M,X}(w), c^*_{M,X}(w)], \\ \frac{1}{\hat{\alpha}}\frac{P_S(w)}{P_M(w)}\frac{\hat{\tau}_S}{\hat{\tau}_M}\frac{\tau_M}{\tau_S}c_M & \text{if } c_M \in (0, \frac{\hat{\tau}_M}{\hat{\tau}_S}c^*_{M,X}(w)], \end{cases} \tag{3.34}$$

where $\hat{\alpha}$ and $\hat{\tau}_k$ are constants. $c^*_k(w)$, $c^*_{k,X}(w)$, and $\hat{c}_S(c_M,w)$ partition the cost space into four disjoint sets, namely $\mathbb{C}_M(w)$ and $\mathbb{C}_S(w)$, which contain the successful entrants in M and S, and $\mathbb{C}^{null}_M(w)$ and $\mathbb{C}^{null}_S(w)$, which contain the unsuccessful entrants.

$$\begin{aligned} \mathbb{C}_M(w) &:= \{c \in \mathbb{R}^2 |\ 0 < c_M \leq c^*_M(w),\ \hat{c}_S(c_M,w) < c_S < \bar{c}\ \}, \\ \mathbb{C}_S(w) &:= \{c \in \mathbb{R}^2 |\ 0 < c_S \leq c^*_S(w),\ \hat{c}_S^{-1}(c_S,w) < c_M < \bar{c}\ \}, \\ \mathbb{C}^{null}_M(w) &:= \{c \in \mathbb{R}^2 |\ c^*_M(w) < c_M \leq \bar{c},\ \hat{c}_S(c_M,w) < c_S < \bar{c}\ \}, \\ \mathbb{C}^{null}_S(w) &:= \{c \in \mathbb{R}^2 |\ c^*_S(w) < c_S \leq \bar{c},\ \hat{c}_S^{-1}(c_S,w) < c_M < \bar{c}\ \}. \end{aligned} \tag{3.35}$$

The set of exporters in each sector is denoted by $\mathbb{C}^X_M(w)$ and $\mathbb{C}^X_S(w)$, where

$$\begin{aligned} \mathbb{C}^X_M(w) &:= \{c \in \mathbb{R}^2 |\ 0 < c_M \leq c^*_{M,X}(w),\ \hat{c}_S(c_M,w) < c_S < \bar{c}\ \} \subseteq \mathbb{C}_M(w), \\ \mathbb{C}^X_S(w) &:= \{c \in \mathbb{R}^2 |\ 0 < c_S \leq c^*_{S,X}(w),\ \hat{c}_S^{-1}(c_S,w) < c_M < \bar{c}\ \} \subseteq \mathbb{C}_S(w). \end{aligned} \tag{3.36}$$

The price indices can be written as

$$\begin{aligned} P_M(w) &= \hat{\sigma}\left[\frac{N_E(w)}{\delta}\left(\iint_{\mathbb{C}_M(w)} c_M^{1-\sigma} + \tau_M^{1-\sigma}\iint_{\mathbb{C}^X_M(w)} c_M^{1-\sigma}\right) dG^c(c|w)\right]^{\frac{1}{1-\sigma}}, \\ P_S(w) &= \hat{\sigma}\left[\frac{N_E(w)}{\delta}\left(\iint_{\mathbb{C}_S(w)} c_S^{1-\sigma} + \tau_S^{1-\sigma}\iint_{\mathbb{C}^X_S(w)} c_S^{1-\sigma}\right) dG^c(c|w)\right]^{\frac{1}{1-\sigma}}, \end{aligned} \tag{3.37}$$

where $N_E(w)$ is the equilibrium mass of entrants. Their ratio satisfies

$$\left(\frac{P_M(w)}{P_S(w)}\right)^{1-\sigma} = \frac{\left[\iint_{\mathbb{C}_M(w)} c_M^{1-\sigma} + \tau_M^{1-\sigma} \iint_{\mathbb{C}_M^X(w)} c_M^{1-\sigma}\right] dG^c(c|w)}{\left[\iint_{\mathbb{C}_S(w)} c_S^{1-\sigma} + \tau_S^{1-\sigma} \iint_{\mathbb{C}_S^X(w)} c_S^{1-\sigma}\right] dG^c(c|w)}. \tag{3.38}$$

As before, using equations 3.28 and 3.33 to 3.38, $\frac{P_M(w)}{P_S(w)}$ can be determined by $c_M^*(w)$. Therefore $c_M^*(w)$ is sufficient to characterize entry decisions of all entrants given w.

The equilibrium value of $c_M^*(w)$ can be solved from the free entry condition

$$\frac{1}{\delta}\left[\iint_{\mathbb{C}_M(w)} \pi_M(c_M, w) + \iint_{\mathbb{C}_S(w)} \pi_S(c_S, w)\right] dG^c(c|w) = f_E, \tag{3.39}$$

where

$$\pi_k(c_k, w) = \mathbb{1}\{c \in \mathbb{C}_k(w)\}\left[\left(\frac{c_k}{c_k^*(w)}\right)^{1-\sigma} - 1\right] f_P + \mathbb{1}\{c \in \mathbb{C}_k^X(w)\}\left[\left(\frac{c_k}{c_{k,X}^*(w)}\right)^{1-\sigma} - 1\right] f_X$$

is the sectoral profit function. It is easy to verify that the equilibrium $c_M^*(w)$ exists and is unique under regulating conditions using the monotonicity of the left-hand size of equation 3.39. The equilibrium mass of entrants $N_E(w)$ can be solved from equations 3.28 and 3.37.

The only variable left unsolved is the skill premium w. I follow section 3.4.1.1 to solve it using the skilled labor market clearing condition:

$$S = \sum_{k=M,S}\left[\iint_{\mathbb{C}_k(w)} S_k(c_k, w) + \iint_{\mathbb{C}_k^X(w)} S_{k,X}(c_k, w)\right] dG^c(c|w), \tag{3.40}$$

where $S_k(c_k, w)$ and $S_{k,X}(c_k, w)$ are defined in equation 3.32. Since the demand of skilled labor is downward sloping in w, a unique solution exists under regulating conditions.

3.4.2 Skill-Biased Technology and Structural Transformation

To best illustrate the effect of skill-biased technology, let me start by comparing the equilibrium outcomes with and without it under independent entry. When technology is Hicks neutral, the share of skilled labor in firms' employment in equation 3.26 reduces to

$$\frac{S_k(z_k, w)}{L_k(z_k, w)} = \frac{\beta_k}{1-\beta_k} w^{-\eta},$$

which is uniform across firms with different productivities. Coupled with the constant markup of the CES demand, it can be shown that the demand for both types of labor is independent of the productivity distribution in each sector, and can thus be deduced from the market clearing conditions similar to equations 3.5. In fact, the share of skilled and unskilled labor employed by sector k can be written as

$$l_k = \frac{L_k}{L} = \frac{\frac{\alpha_k}{\hat{\sigma}}\left(1+\left(\frac{\beta_k}{1-\beta_k}w^{1-\eta}\right)\right)^{-1} + \frac{\alpha_k}{\sigma}}{\sum_k \left[\frac{\alpha_k}{\hat{\sigma}}\left(1+\left(\frac{\beta_k}{1-\beta_k}w^{1-\eta}\right)\right)^{-1} + \frac{\alpha_k}{\sigma}\right]},$$

$$s_k = \frac{S_k}{S} = \frac{\frac{\alpha_k}{\hat{\sigma}}\left(\frac{\beta_k}{1-\beta_k}w^{1-\eta}\right)\left(1+\left(\frac{\beta_k}{1-\beta_k}w^{1-\eta}\right)\right)^{-1}}{\sum_k \frac{\alpha_k}{\hat{\sigma}}\left(\frac{\beta_k}{1-\beta_k}w^{1-\eta}\right)\left(1+\left(\frac{\beta_k}{1-\beta_k}w^{1-\eta}\right)\right)^{-1}}.$$

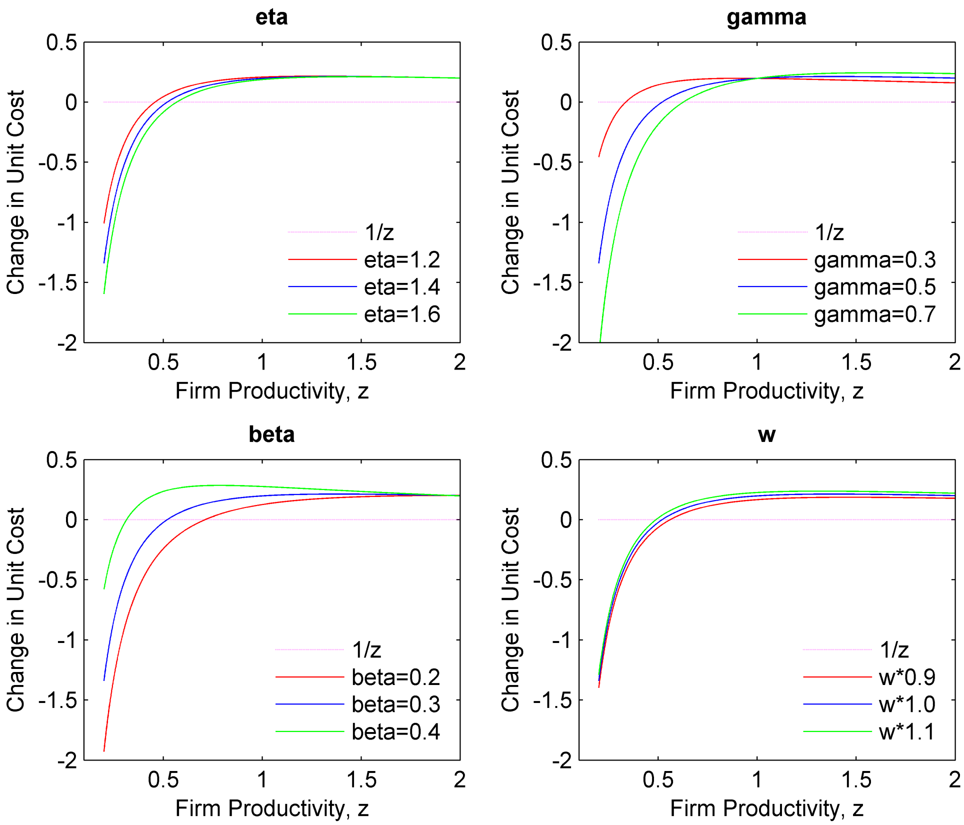
While trade liberalization alters the equilibrium distribution and mass of incumbent firms, it is unable to change the relative demand of either types of labor. Hence, the skill premium does not respond to any reduction in trade cost, making the above shares invariant to any trade liberalization. For this reason, there is no structural transformation in this model with Hicks neutral technology and independent entry.

However, when technology is skill-biased, the employment shares of both types of labor depend on the equilibrium distribution of incumbent firms. Recall the skilled-biased technology mechanism. A reduction in τ_M induces the typical Melitz selection within M, increasing the production cutoff productivity z_M^* and decreasing the export cutoff $z_{M,X}^*$. This improves the average productivity of M firms and hence elevates the relative demand of skilled labor, raising the skill premium. Since sales decrease for the less productive firms in M which are also less skill intensive, job destruction is disproportionally higher for the unskilled labor. If unskilled labor is the major factor of production, this destruction will dominate the increasing demand of skilled labor, yielding a smaller share of manufacturing employment and a higher skill intensity in the sector.

The above result seems to suggest that skill-biased technology has similar effect on structural transformation as selective entry, because both of them tend to reallocate labor away from the liberalizing sector. Therefore, when coexist, they can strengthen structural transformation. But the result is not as easy as intuition would suggest. In fact, skill-biased technology tends to inhibit structural transformation under selective entry. The stronger the bias, the lesser the structural transformation.

The reason that skill-biased technology works against the reallocation mechanism of selective entry lies with the cost function. Figure 3.11 shows the change in unit costs across firms under different parameterizations of the unit cost function in equation 3.25. It is clear that when skilled labor is more expensive and relatively scarcer, increasing bias towards skilled labor will flatten cost variations, reducing the unit cost of the less productive firms while raising that of the more productive ones.

These changes in the unit cost function have several implications. First, by equation 3.39, higher unit costs in firms in the right tail of the productivity distribution imply a higher cutoff cost for entry, or equivalently a lower entry cutoff productivity, and thus a lower export cutoff productivity. As shown by Figure 3.12, these lower cutoffs shift the equi-profit line after trade liberalization to the left, producing a higher ex-post probability of entering into the liberalizing when compared with the case without skill-biased technology. Consequently, the suppression of job creation in the entry segment of the liberalizing sector is alleviated. In

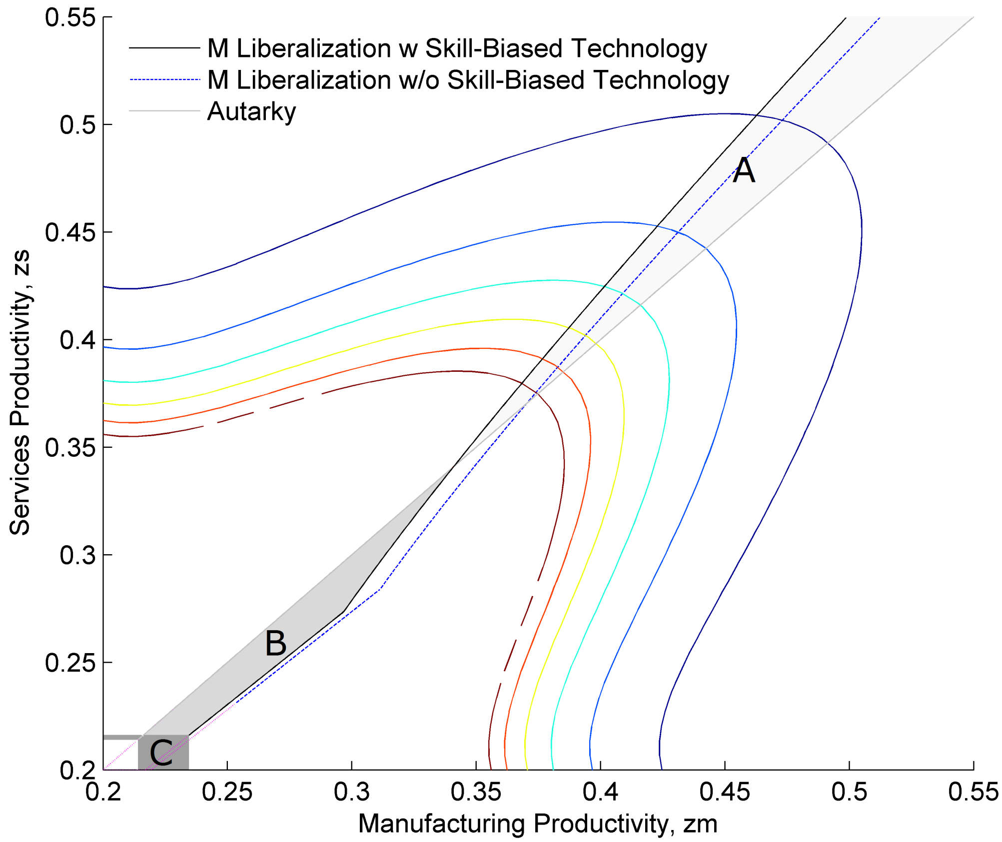


Remark: This panel displays the difference between the unit cost function in equation 3.25 with skill-biased technology and the simple unit cost function in equation 3.4 under different parameterizations and values of skill premium w. The dotted horizontal line across 0 means no change in unit cost. The base parameterization (blue line) is $\beta_k = 0.3$, $\gamma = 0.5$ and $\eta = 1.4$.

Figure 3.11. The Change in Unit Cost with Skill-Biased Technology

addition, a flatter unit cost function dampens the difference between firms' sales and profits. Therefore, it attenuates the exaggeration of the job destruction in the less productive firms of the liberalizing sector caused by selective entry. Moreover, increasing skill biased can lift up the demand of skilled labor after reduction in trade cost in the liberalizing sector. The increase in skilled labor employment can partially offset the decrease in unskilled labor employment.

In short, skill-biased technology can improve sectoral skill intensity after trade liberalization. However, it tends to inhibit the structural transformation triggered by selective entry.



Remark: The solid black line is the equi-profit line after reduction in τ_M. Firms with productivity draws above the line will enter into S, while those below the line will enter into M. For comparison, the grey line is the autarky equi-profit line and the dotted blue line is that without skill-biased technology. The contour lines represent the density of the selective distribution. The area labelled A contains the S entrants who will enter into M after t_M reduction, area B contains the M entrants that move into S, and area C are the exiting manufacturing and services firms.

Figure 3.12. The Equi-Profit Line and Trade Liberalization in Manufacturing Sector

The magnitude of structural transformation in the extended model thus crucially depends on the shape of the unit cost function. Therefore, parameterization of the cost function is of first order importance to firms' entry decisions and the distribution of profits and labor within and across sectors, which I will demonstrate in the next section.

Basic Model			
Sectoral Share of Expenditures	α_k	0.5	
Elasticity of Substitution, Varieties	σ	3.8	$*\dagger$
Location of Pareto Distribution	T	0.2	$*\natural\dagger$
Dispersion of Pareto Distribution	θ	4.582	$*\dagger$
Probability of Bad Shock	δ	0.025	$*\natural\dagger$
Production Fixed Cost	f_P	0.043	$*\dagger$
Export Fixed Cost	f_X	0.0588	$\dagger$
Entry Cost	f_E	2	$*\natural\dagger$
Selective Entry			
Correlation of Copula	ρ	0.5	
Skill-Biased Technology			
Elasticity of Substitution, Skills	η	1.4	$\ddagger$
Sectoral Skill Intensity	β_k	0.5	
Skill-Bias in Technology	γ	0.5	$\ddagger$

Source: $*$ Balistreri et al. (2011), $\natural$ Bernard et al. (2007), $\ddagger$ Burstein and Vogel (2012), $\dagger$ Segerstrom and Sugita (2013).

Table 3.2. Basic Parameterization

3.5 Numerical Implementations

This section aims to quantify the effects of trade liberalization on structural transformation under selective entry and skill-biased technology. I will borrow parameter values from a series of existing works to demonstrate the aforementioned effects, and present related comparative statics.

When economies are symmetric and sectors are identical except in τ_k, there are only twelve parameters need to be set, eight from the basic model, one from the selective entry assumption and three from the skill-bias in technology. Table 3.2 lists all the values of the parameters. The last column of indicates the sources where the values are obtained. I set $\alpha_M = \alpha_S = 0.5$ to control for the relative size of the sectors. $\beta_M = \beta_S = 0.5$ are set to eliminate distortions due to differences in sector specific factor intensities. The choice of ρ is rather arbitrary. Sensitivity analyses will be performed over alternative choices of ρ, η, γ and

M	Autarky	$\tau_M = 1.6$	$\tau_M = 1.2$	$\tau_M = 1.0$
Independent Entry				
Entry Cutoff	0.214	0.218	0.228	0.243
Export Cutoff	∞	0.390	0.306	0.272
Mass of Firms	1.190	1.087	0.878	0.654
Employment Share	0.500	0.500	0.500	0.500
Welfare, L	0.117	0.118	0.121	0.125
Selective Entry				
Entry Cutoff	0.230	0.235	0.246	0.263
Export Cutoff	∞	0.420	0.331	0.294
Mass of Firms	1.144	0.995	0.729	0.512
Employment Share	0.500	0.488	0.465	0.446
Welfare, L	0.126	0.128	0.131	0.136
Selective Entry and Skill-Biased Technology				
Entry Cutoff	0.212	0.216	0.226	0.243
Export Cutoff	∞	1.332	0.321	0.278
Mass of Firms	1.467	1.328	0.995	0.674
Employment Share	0.500	0.490	0.467	0.446
Skill Intensity	0.200	0.207	0.222	0.235
Welfare, L	0.119	0.120	0.122	0.126
Welfare, S	0.175	0.178	0.183	0.189

$\alpha_M = 0.5,\ \beta_M = \beta_S = 0.5,\ \tau_S = 5.$

Table 3.3. Numerical Results of M under Basic Parameterization

β_k. Last but not least, since scaling up the labor force does not change the key equilibrium objects, I normalize $L = 1$ in the case of homogeneous labor and $S + L = 1$ when labor is heterogeneous, with $S = 0.2$ obtained from the OES data.

The independent variable in the following exercise is τ_M. Its reduction represents liberalizing in manufacturing trade. Table 3.3 and 3.4 present selected equilibrium outcomes of both sectors at different levels of τ_M in different versions of the model. Except in autarky, $\tau_S = 5$ is fixed throughout the exercise. In the basic parameterization, liberalizing sector M from autarky to free trade under selective entry decreases M's employment share by more than 10%, ceteris paribus.[11] The same statistic under independent entry is 0%. When

[11] Free trade refers to $\tau_M = 0$, but the export fixed cost is still positive.

S	Autarky	$\tau_M = 1.6$	$\tau_M = 1.2$	$\tau_M = 1.0$
Independent Entry				
Entry Cutoff	0.214	0.214	0.214	0.214
Export Cutoff	∞	1.194	1.194	1.194
Mass of Firms	1.190	1.190	1.190	1.190
Employment Share	0.500	0.500	0.500	0.500
Welfare, L	0.117	0.118	0.121	0.125
Selective Entry				
Entry Cutoff	0.230	0.230	0.231	0.231
Export Cutoff	∞	1.286	1.290	1.292
Mass of Firms	1.144	1.196	1.280	1.338
Employment Share	0.500	0.512	0.535	0.554
Welfare, L	0.126	0.128	0.131	0.136
Selective Entry and Skill-Biased Technology				
Entry Cutoff	0.212	0.213	0.214	0.215
Export Cutoff	∞	1.429	1.437	1.443
Mass of Firms	1.467	1.532	1.661	1.764
Employment Share	0.500	0.510	0.533	0.554
Skill Intensity	0.200	0.193	0.181	0.172
Welfare, L	0.119	0.120	0.122	0.126
Welfare, S	0.175	0.178	0.183	0.189

$\alpha_M = 0.5,\ \beta_M = \beta_S = 0.5,\ \tau_S = 5.$

Table 3.4. Numerical Results of S under Basic Parameterization

technology is skill-biased, it also results in a 17.5% increase in M's skill intensity. In a moderate trade liberalization by reducing τ_M from 1.6 to 1.2, M's employment share decreases by 4.6% under selective entry. Including skill-biased technology slightly lessens structural transformation but increases M's skill intensity by 7.0%. In addition, skilled labor enjoys higher welfare gains at 2.8%, whereas unskilled labor only gains 1.9%. In other words, trade liberalization will raise income inequality when technology is skill-biased.

The magnitude of structural transformation crucially depends on the parameters introduced in selective entry and skill-biased technology. To illustrate this, table 3.5 shows the sensitivity of the results in M to the correlation parameter between the Pareto marginals. Each number in the table represents the percentage change after a moderate trade liberaliza-

M, %	Independent	$\rho = 0.25$	$\rho = 0.50$	$\rho = 0.75$
Selective Entry				
Entry Cutoff	4.99	4.95	5.03	5.25
Export Cutoff	-21.28	-21.29	-21.23	-21.05
Mass of Firms	-20.32	-22.42	-26.72	-38.97
Employment Share	-2.98	-3.54	-4.59	-7.07
Welfare	2.55	2.55	2.60	2.87

$\alpha_M = 0.5,\ \tau_S = 5,\ \tau_M = 1.6, 1.2.$

Table 3.5. Sensitivity to ρ under Basic Parameterization

tion in M by reducing τ_M from 1.6 to 1.2. Clearly, structural transformation increases with ρ, from less than 3.0% when marginals are independent to 7.1% when their correlation is 0.75. Intuitively, a higher ρ makes the joint density more concentrated around the 45-degree line. Therefore, any tilt in the equi-profit line will result in sharper decrease in the probability density, yielding a much smaller mass of M firms and lower share of employment.

The next exercise illustrates the sensitivity of the results to the degrees of skill-bias in technology. Table 3.6 shows the percentage change in equilibrium outcomes after a moderate liberalization in M under different combinations of γ, η and β_k. Increasing skill-bias through γ and η inhibits structural transformation for reasons discussed in section 3.4.2. It also redistributes gains from trade towards skill-labor. But the results are not very responsive to changes in these parameters. On the contrary, the effect of varying β_k can significant. A 0.1 increase in β_k produces similar changes in the results as switching γ and η to Hick-neutral. One difference is that a larger β_k when technology is skill-biased allows both factors to enjoy higher gains from trade.

3.6 Conclusion

In most trade models, comparative advantage is at the heart of structural transformation induced by reductions in trade costs. However, recent evidences at the firm and individual level point out that neither exporters nor the comparative advantage sectors absorb trade displaced labor. Using the OES data published by BLS and the industry level trade data, I find similar results in the U.S. labor market since 2001. In particular, industries' employment share generally decreases with the level of trade liberalization, regardless of sectors. Meanwhile, industries' skill intensity increases as liberalization deepens.

This paper presents a model of structural transformation in an open economy that does not rely on the forces of comparative advantage. When entrants can respond to the changing market conditions in different sectors by deciding which sector to enter based on their potential capabilities, the liberalizing sector will be less appealing to less productive entrants because trade liberalization decreases their potential profits. As a result, structural transformation occurs as trade liberalization exaggerates job destruction among less productive incumbent firms and suppresses job creation in the entry segment of the liberalizing sector. Furthermore, when there is heterogeneity in labor skills and the production technology is skill-biased, the liberalizing sector's skill intensity will increase along with its decreasing employment share.

Although this model is able to generate reallocation patterns that are consistent with the empirics, a more precise quantification of its impact requires further evidence beyond firms' revealed entry choice. For instance, future studies may focus on how to identify entrants' unobserved capabilities outside their sectors of entry, and test if firms' entry decision reacts to profit opportunities in other sectors.

M, %	Hicks Neutral	$\gamma = 0.25$	$\gamma = 0.50$
Selective Entry and Skill-Biased Technology			
Entry Cutoff	5.03	4.92	4.73
Export Cutoff	-21.23	-22.54	-25.05
Mass of Firms	-26.73	-26.21	-25.10
Employment Share	-5.42	-5.13	-4.57
Skill Intensity	5.73	6.35	6.96
Welfare, L	2.60	2.31	1.92
Welfare, S	2.60	2.74	2.82

$\alpha_M = 0.5,\ \beta_k = 0.5,\ \eta = 1.4,\ \tau_S = 5,\ \tau_M$ reduces from 1.6 to 1.2.

M, %	Hicks Neutral	$\eta = 1.20$	$\eta = 1.40$
Selective Entry and Skill-Biased Technology			
Entry Cutoff	5.03	4.87	4.73
Export Cutoff	-21.23	-23.35	-25.05
Mass of Firms	-26.73	-25.96	-25.10
Employment Share	-5.85	-5.13	-4.57
Skill Intensity	6.21	6.35	6.96
Welfare, L	2.60	2.19	1.92
Welfare, S	2.60	2.70	2.82

$\alpha_M = 0.5,\ \beta_k = 0.5,\ \gamma = 0.5,\ \tau_S = 5,\ \tau_M$ reduces from 1.6 to 1.2.

M, %	$\beta_k = 0.50$	$\beta_k = 0.60$	$\beta_k = 0.70$
Selective Entry and Skill-Biased Technology			
Entry Cutoff	4.73	5.03	5.28
Export Cutoff	-25.05	-22.95	-20.80
Mass of Firms	-25.10	-26.32	-27.47
Employment Share	-4.57	-5.75	-7.27
Skill Intensity	6.96	7.99	9.22
Welfare, L	1.92	2.12	2.38
Welfare, S	2.82	3.04	3.29

$\alpha_M = 0.5,\ \eta = 1.4,\ \gamma = 0.5,\ \tau_S = 5,\ \tau_M$ reduces from 1.6 to 1.2.

Table 3.6. Sensitivity to *beta*, γ and η under Basic Parameterization

Appendix A

Data and Procedures

This appendix contains detailed descriptions of the data sources and related procedures. The major data sources include the OECD StatExtracts data interface, WIOD, UNIDO, Comtrade, WTO, World Bank, Penn World Tables and CEPII.

A.1 Scope and Definitions

Table A.1 is the list of countries studies in the numerical analysis in Chapters 1 and 2. Table A.2 defines the sector classification used in Chapter 1. Industries are divided into three sectors: manufacturing (M), services (S), and the rest of economy (R). Table A.3 lists the industries included in the WIOD tables used in Chapter 2. These industries are grouped into 4 sectors: agriculture (A), manufacturing (M), services (S), and others (O).

A.2 Bilateral Trade Data

One remarkable advantage of the OECD StatExtracts data is that most trade and production are available in ISIC Rev.3 classifications, which eliminates the need of concordances

Country	Chapter 1	Chapter 2	OECD
Australia	√	√	√
Austria	√	√	√
Belgium		√	√
Brazil		√	
Bulgaria		√	
Canada	√	√	√
China		√	
Cyprus		√	
Czech	√	√	√
Denmark	√	√	√
Estonia		√	
Finland	√	√	√
France	√	√	√
Germany	√	√	√
Greece	√	√	√
Hungary	√	√	√
Indonesia		√	
India		√	
Ireland	√	√	√
Italy	√	√	√
Japan	√	√	√
Korea	√	√	√
Lithuania		√	
Luxembourg		√	√
Latvia		√	
Mexico		√	√
Malta		√	
Netherlands		√	√
Norway	√		√
Poland	√	√	√
Portugal	√	√	√
Romania		√	
Russia		√	
Slovak	√	√	√
Slovenia	√	√	
Spain	√	√	√
Sweden	√	√	√
Turkey		√	√
Taiwan		√	
U.K.	√	√	√
U.S.	√	√	√

Table A.1. List of Countries

Industry	ISIC Rev.3	Sector
Agriculture, Hunting, Forestry and Fishing	01-05	
Mining and Quarrying	10-14	R
Electricity, Gas and Water Supply	40-41	
Manufacturing	15-37	M
Construction	45	
Wholesale, Retail Trade, Restaurants and Hotels	50-55	
Transport, Storage and Communications	60-64	S
Finance, Insurance and Business Services	65-74	
Community, Social and Personal Services	75-99	

Note: STAN Industry List: http://www.oecd.org/industry/industryandglobalization/1830838.htm

Table A.2. Sector Definition and ISIC Rev.3 Classification

and reduces the preparation effort needed to decompose and re-consolidate the data. The world input-output table is even cleaner as the developer deployed consistent estimation and interpolation methods across industries and countries, and the trade, production and consumption data is presented in one unified view.

For Chapter 1, I used the bilateral trade data of 2008 from OECD StatExtracts. In particular, the International Trade and Balance of Payments dataset in OECD StatExtracts provides EBOPS data for trade in services among most OECD countris and their major trade partners. It includes aggregate bilateral trade services flows between countries and some limited industry level details. Only the aggregate flows are used in Chapter 1. The average discrepancy between reported export and import values is 23% much higher than the goods trade. To reconcile the two statistics of the same trade flow, I followed Leeuwen and Lejour (2006) to clean the data. The manufacturing trade flows are extracted from the OECD STAN Bilateral Trade by Industry and End-Use dataset. The average discrepancy between export and import is less than 3%. Import is assumed to be the accurate statistic and is used as the final trade flows for manufacturing. Sectoral trade deficits for both sectors are calculated from the trade flows. To ensure data quality, I compared the deficits calculated from the UN Comtrade and UN Services Trade databses. The two sources yield comparable

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

Table A.3. Industry Definition in WIOD Input-Output Tables deficits with average discrepancies below 5%. To calculate deficits for the other sectors, I consulted the OECD STAN database again and validated the results with the UN Comtrade counterparts. Total deficits are obtained from the sectoral deficits.

For Chapter 2, I used the WIOD World Input Output Table for all trade flows. Their data is derived from the UN Comtrade, OECD and other sources. I validated a random sub-sample of country-level manufacturing deficits and sector level aggregate flows against the UN Comtrade and OECD International Trade and Balance of Payments. The average discrepancy is below 5%. In addition, I validated a random sample of bilateral services flow among OECD countries against the OECD StatExtracts. The average discrepancy is slightly above 6%.

A.3 Sectoral Price Indices

The Prices and Price Indices dataset in OECD.StateExtracts provides price indicies ratios used in Chapter 1. Producer price indices (PPI) for manufacturing are available for each of the 23 countries in the sample in Chapter 1. However, they are normalized against the 2005 price levels. To make cross-country comparison possible, I used the OECD 2005 PPP Benchmark results to construct proxies for the 2005 PPI. The final PPI are then taken as the product of the proxies for 2005 and the 2008 to 2005 ratios. The OECD.StatExtracts also provides 2008 PPP Benchmark results, so another set of direct procies for 2008 PPI was computed. The two sets are comparable after proper normalizations. The PPI for services is much harder to find. I took the price levels for total services from OECD 2008 PPP Benchmark results as proxies since the definition of services sector covers most of the sub-categories. An additional set of consumer price indices (CPI) for total services can also be found in OECD StatExtracts, which only covers half of the countries in the sample. But the price ratios obtained from our proxies compare well against the available CPI ratios.

A.4 Sectoral Output

OECD STAN database provides detailed breakdown of annual gross output by industry according to the ISIC Rev.3 classification. I follow the sector definitions to aggregate the industy level output. Two issues should be addressed here. First, the gross output numbers are only reported in the national currency. To convert them into dollars, I used the average exchange rates in 2008 computed from Yahoo! Finance. Second, the STAN results do not cover all countries in our sample. To complete the dataset, I used the value-added data from the UNIDO database and value-added share of goss output calculated from STAN 2005 Input-Output table to back out the missing sectoral gross output. The UNIDO data also served as a validation to the results. In Chapter 2, the WIOD input-output tables directly provide the output of each industry. Industry output in Chapter 2 are directly read from the WIOD input-output tables.

A.5 Input-Output Coefficients

In Chapter 1, the value-added shares are obtained by dividing the total value-added by the output for each sector. For countries that are not present in the STAN output databsase, I used the corresponding share in the 2005 STAN Input-Output Table, assuming that it remains stable from 2005 to 2008. The intermediate input shares are also from the 2005 Input-Output Table. In Chapter 2, those shares are directly computed from the WIOD input-output tables.

A.6 Gravity and Other Macro Data

To model proxies for trade frictions, I used the CEPII Gravity dataset to contruct the dummies for diatance, language, colonial ties, border, trade agreement and time zone differences.

To get accurate trade agreement for sectors, I directly consulted the WTO table of existing treaties. In both chapter, I did not distinguish different types of treaties other than its broad sector coverage, for example, EU and NAFTA is assumed to have the same effect on trade in the model.

National GDP and labor forces are obtained from the World Bank database. Each country's wage is taken as the ratio of GDP and labor force. In Chapter 1. the share of sectoral expenditure share are calculated by dividing country's final spending on each sector by total final spendings obtained from the STAN 2005 Input-Output Table. These shares calculated similarly using WIOD input-output tables in chapter 2. Additional macro data used in Chapter 2 like capital stock and human capital index are obtained from the Penn World Table 8.0.

Appendix B

Solving for the Equilibrium

In this appendix, I will describe the algorithm used to solve fore the counterfactual equilibria in Chapter 1 and 2. The algorithm is mainly inspired by Eaton et al. (2011). The algorithm is implemented in Matlab. A copy of the main solution step is included at the end of this appendix.

Recall the definition of the global equilibrium: Given labor endowment L_i, final demand parameters α_{ij} and σ_j, the input-output shares β_{ij} and γ_{ijl}, deficits D_i, productivity distribution T_{ij} and θ_j, and trade fictions d_{inj} for each i and j, the global equilibrium is a set of wages w_i, prices p_{ij} and trade flows X_{nij} that jointly solve

$$\begin{aligned} X_{ij} =& \alpha_{ij}\left(Y_i^F + D_i\right) + \sum_{l\in\Omega} \gamma_{ilj}\left(1-\beta_{il}\right)\left(\sum_{n=1}^{I} \pi_{nil} X_{nl}\right), \\ \pi_{nij} =& \frac{X_{nij}}{X_{nj}} = \frac{T_{ij}\left(c_{ij} d_{nij}\right)^{-\theta_j}}{\sum_{k=1}^{I} T_{kj}\left(c_{kj} d_{nkj}\right)^{-\theta_j}}, \\ P_{nj} =& \Gamma_j \left[\sum_{i=1}^{I} T_{ij}\left(c_{ij} d_{nij}\right)^{-\theta_j}\right]^{-\frac{1}{\theta_j}}, \\ c_{ij} =& w_i^{\beta_{ij}} \prod_{l\in\Omega} \left(P_{il}\right)^{(1-\beta_{ij})\gamma_{ijl}}. \end{aligned} \tag{B.1}$$

Sectorl gross output Y_{ij}, deficits D_{ij} and emloyment levels L_{ij} are given by

$$\begin{aligned} Y_{ij} =& \sum_{n=1}^{I} \pi_{nij} X_{nj}, \\ D_{ij} =& X_{ij} - Y_{ij}, \\ L_{ij} =& \beta_{ij} Y_{ij} / w_i. \end{aligned} \tag{B.2}$$

Given a vector of wage $\hat{w}$, we can iteratively solve for the implied price system using the third and fourth equations of B.1. The implied prices and $\hat{w}$ together allows us to compute π_{nij} defined in the second equation of B.1. Given the trade share matrix and the deficits, we can then use the first equation of B.1 to solve for the spending levels in each country. The market clearing conditions in equation B.2 is checked against the results. If the market does not clear, $\hat{w}$ is adjusted in the appropricate direction. These steps are repeated until convergence.

Bibliography

Aadiya, M., Stern, R. M., and Zanini, G. (2008). *A Handbook of International Trade in Services*.

Acemoglu, D. and Guerrieri, V. (2008). Capital Deepening and Nonbalanced Economic Growth. *Journal of Political Economy*, 116(3):467–498.

Acemoglu, D. and Zilibotti, F. (2001). Productivity Differences. *Quarterly Journal of Economics*, 116(2):563–606.

Alvarez, F., Buera, F. J., and Lucas, R. E. (2013). Idea flows, Economic Growth, and Trade. Working Paper 19667, NBER.

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

Anderson, J. E. (1979). A Theoretical Foundation for the Gravity Equation. *American Economic Review*, 69(1):106–116.

Anderson, J. E., Milot, C., and Yotov, Y. (2010). The Surprisingly Swift Decline of U.S. Manufacturing Employment. Working paper, DFAIT.

Anderson, J. E. and van Wincoop, E. (2003). Gravity with Gravitas: a Solution to the Border Puzzle. *American Economic Review*, 93(1):70–92.

Arkolakis, C., Ramondo, N., Rodriguez-Clare, A., and Yeaple, S. (2013). Innovation and Production in the Global Economy. NBER Working Papers 18972, National Bureau of Economic Research, Inc.

Artuc, E., Chaudhuri, S., and McLaren, J. (2010). Trade Shocks and Labor Adjustment: A Structural Empirical Approach. *American Economic Review*, 100(3):1008–45.

Autor, D. H., Dorn, D., and Hanson, G. H. (2013). The China Syndrome: Local Labor Market Effects of Import Competition in the United States. *American Economic Review*, 103(6):2121–68.

Baily, M. N. and Bosworth, B. P. (2014). US Manufacturing: Understanding Its Past and Its Potential Future. *Journal of Economic Perspectives*, 28(1):3–26.

Baily, M. N. and Lawrence, R. Z. (2004). What Happened to the Great U.S. Job Machine? The Role of Trade and Electronic Offshoring. *Brookings Papers on Economic Activity*, 35(2):211–284.

Balistreri, E. J., Hillberry, R. H., and Rutherford, T. F. (2011). Structural estimation and solution of international trade models with heterogeneous firms. *Journal of International Economics*, 83(2):95–108.

Barro, R. J. (1991). Economic Growth in a Cross Section of Countries. *Quarterly Journal of Economics*, 106(2):407–443.

Barro, R. J. and Sala-i Martin, X. (1992). Convergence. *Journal of Political Economics*, 100(2):223–251.

Bernard, A. B., Eaton, J., Jensen, J. B., and Kortum, S. (2003). Plants and Productivity in International Trade. *American Economic Review*, 93(4):1268–1290.

Bernard, A. B., Jensen, B. J., and Schott, P. K. (2006). Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants. *Journal of International Economics*, 68(1):219–237.

Bernard, A. B. and Jones, C. I. (1996a). Comparing Apples to Oranges: Productivity Convergence and Measurement Across Industries and Countries. *American Economic Review*.

Bernard, A. B. and Jones, C. I. (1996b). Technology and Convergence. *Economic Journal*.

Bernard, A. B., Redding, S. J., and Schott, P. K. (2007). Comparative Advantage and Heterogeneous Firms. *Review of Economic Studies*, 74(1):31–66.

Betts, C., Giri, R., and Verma, R. (2013). Trade, Reform, And Structural Transformation in South Korea. MPRA Paper 49540, University Library of Munich, Germany.

Buera, F. J. and Kaboski, J. P. (2009). Can Traditional Theories of Structural Change Fit The Data? *Journal of the European Economic Association*, 7(2-3):469–477.

Burstein, A. and Vogel, J. (2012). International trade, technology, and the skill premium. Technical report.

Caliendo, L. and Parro, F. (2009). Estimates of the Trade and Welfare Effects of NAFTA. Working Paper 18508, NBER.

Caselli, F. and II, W. J. C. (2001). The U.S. Structural Transformation and Regional Convergence: A Reinterpretation. *Journal of Political Economy*, 109(3):584–616.

Chenery, H. B. and Syrquin, M. (1976). Patterns of Development, 1950-1970. *African Economic History*, (2):56–58.

Chor, D. (2010). Unpacking Sources of Comparative Advantage: A Quantitative Approach. *Journal of International Economics*, 82(2):152–167.

Clark, C. (1957). *The Conditions of Economic Progress.*

Costinot, A., Donaldson, D., and Komunjer, I. (2012). What goods do countries trade? A Quantitative Exploration of Ricardo's Ideas. *Review of Economic Studies*, 79(2):581–608.

Coar, A. K., Guner, N., and Tybout, J. (2011). Firm dynamics, job turnover, and wage distributions in an open economy. Working Papers 2011-06, Instituto Madrileo de Estudios Avanzados (IMDEA) Ciencias Sociales.

Deardorff, A. V. (1980). The General Validity of the Law of Comparative Advantage. *Journal of Political Economy*, 88(5):941–957.

Dekle, R., Eaton, J., and Kortum, S. (2008). Global Rebalancing with Gravity: Measuring the Burden of Adjustment. Staff Papers 55(3), IMF.

Dix-Carneiro, R. (2010). Trade Liberalization and Labor Market Dynamics. Working Papers 1273, Princeton University, Department of Economics, Center for Economic Policy Studies.

Dix-Carneiro, R. (2012). Trade Reform and Reallocation: What Have We Learned and What is Next? Working papers, University of Maryland.

Duarte, M. and Restuccia, D. (2010). The Role of the Structural Transformation in Aggregate Productivity. *The Quarterly Journal of Economics*, 125(1):129–173.

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

Eaton, J., Kortum, S., Neiman, B., and Romalis, J. (2011). Trade and the Global Recession. NBER Working Papers 16666, National Bureau of Economic Research, Inc.

Echevarria, C. (1997). Changes in Sectoral Composition Associated with Economic Growth. *International Economic Review*, 38(2):431–52.

Egger, P., Larch, M., and Staub, K. E. (2012). Trade Preferences and Bilateral Trade in Goods and Services: A Structural Approach. Discussion Papers 9051, CEPR.

Fajgelbaum, P. and Redding, S. J. (2014). External Integration, Structural Transformation and Economic Development: Evidence from Argentina 1870-1914. NBER Working Papers 20217, National Bureau of Economic Research, Inc.

Feenstra, R. C. (2004). *Advanced International Trade: Theory and Evidence.*

Finicelli, A., Pagano, P., and Sbracia, M. (2013). Ricardian selection. *Journal of International Economics*, 89(1):96–109.

Finicelli, A., Patrizio, P., and Sbracia, M. (2009). Trade-revealed TFP. Working Paper 729, Bank of Italy.

Fisher, A. G. B. (1939). Production, Primary, Secondary and Tertiary. *Economic Record*, 15(1):24–38.

Foellmi, R. and Zweimller, J. (2008). Structural change, Engel's consumption cycles and Kaldor's facts of economic growth. *Journal of Monetary Economics*, 55(7):1317–1328.

Francois, J. (2001). The Next WTO Round: North-South Stakes in New Market Access Negotiations. Technical Report 0863964745, Adelaide Centre for International Economic Studies.

Francois, J., Pindyuk, O., and Woerz, J. (2008). Trade effects of services trade liberalization in the EU. Research Report 004, FIW.

Francois, J., Pindyuk, O., and Woerz, J. (2009). Trends in International Trade and FDI in Services. Discussion paper 200908-02, IIDE.

Francois, J., van Meijl, H., and van Tongeren, F. (2003). Economic Benefits of the Doha Round for the Netherlands. Research report, LEI.

Francois, J. and Woerz, J. (2008). Producer services, Manufacturing Linkages, and Trade. *Journal of Industry Competition and Trade*, 8(3):199–229.

Galor, O. and Mountford, A. (2008). Trading Population for Productivity: Theory and Evidence. *Review of Economic Studies*, 75(4):1143–1179.

Goldberg, P. K. and Pavcnik, N. (2007). Distributional Effects of Globalization in Developing Countries. *Journal of Economic Literature*, 45(1):39–82.

Gollin, D., Parente, S., and Rogerson, R. (2002). The Role of Agriculture in Development. *American Economic Review*, 92(2):160–164.

Grunfeld, L. A. and Moxnes, A. (2003). The Intangible Globalization: Explaining Patterns of International Trade in Services. Discussion paper 657, Norwegian Institute of International Affairs.

Hansen, G. D. and Prescott, E. C. (2002). Malthus to Solow. *American Economic Review*, 92(4):1205–1217.

Hanson, G. H., Lind, N., and Muendler, M.-A. (2015). The Dynamics of Comparative Advantage. Working Paper 21753, NBER.

Hausmann, R. and Klinger, B. (2007). The Structure of the Product Space and the Evolution of Comparative Advantage. Working Paper 146, CID.

Head, K. and Ries, J. (2001). Increasing Returns versus National Product Differentiation as an Explanation for the Pattern of U.S.-Canada Trade. *American Economic Review*, 91(4):858–876.

Helpman, E., Itskhoki, O., and Redding, S. (2010). Trade and Labor Market Outcomes. CEP Discussion Papers dp1028, Centre for Economic Performance, LSE.

Herrendorf, B., Rogerson, R., and kos Valentinyi (2014). Growth and Structural Transformation. In *Handbook of Economic Growth*, volume 2 of *Handbook of Economic Growth*, chapter 6, pages 855–941. Elsevier.

Hsieh, C.-T. and Ossa, R. (2011). A Global View of Productivity Growth in China. Working Paper 16778, NBER.

Jones, R. (1979). Technical Progress and Real Income in a Recardian Trade Model. International Trade: Essays in Theory. Amsterdam: North-Holland.

Keller, W. (2004). International Technology Diffusion. *Journal of Economic Literature*, 42(3):752–782.

Kimura, F. and Lee, H.-H. (2006). The Gravity Equation in International Trade in Services. *Review of World Economics*, 142(1):92–121.

Kletzer, L. (2003). Trade-related Job Loss and Wage Insurance: A Synthetic Review. Santa Cruz Center for International Economics, Working Paper Series qt27w182ht, Center for International Economics, UC Santa Cruz.

Kongsamut, P., Rebelo, S., and Xie, D. (2001). Beyond Balanced Growth. *Review of Economic Studies*, 68(4):869–82.

Kox, H. and Lejour, A. (2005). Regulatory Heterogeneity as Obstacle for International Services Trade. Discussion paper 49, CPB.

Krugman, P. (1979). A Model of Innovation, Technology Transfer, and the World Distribution of Income. *Journal of Political Economy*, 87(2):253–266.

Kuralbayeva, K. and Stefanski, R. (2013). Windfalls, structural transformation and specialization. *Journal of International Economics*, 90(2):273–301.

Kuznets, S. (1966). *Modern Economic Growth: Rate, Structure, and Spread*.

Lawrence, R. Z. and Edwards, L. (2013). US Employment Deindustrialization: Insights from History and the International Experience. Policy Briefs PB13-27, Peterson Institute for International Economics.

Lejour, A. and de Paiva Verheijden, J. (2006). Services Trade Within Canada and the European Union: What do They Have in Common? Discussion Paper 42, CPB.

Lennon, C. (2006). Trade in Services and Trade in Goods: Differences and Complementarities. Working Paper 53, WIIW.

Levchenko, A. A. and Zhang, J. (2011). The Evolution of Comparative Advantage: Measurement and Welfare Implications. Working Paper 16806, NBER.

Lucas, R. E. (2009). Trade and the Diffusion of the Industrial Revolution. *American Economic Journal: Macroeconomics*, 1:1–25.

Lurweg, M., Oelgemller, J., and Westermeier, A. (2010). Structural Change in an Open Economy. Working Paper 19, Centrum fr Angewandte Wirtschaftsforschung Mnster.

Mankiw, G. N. and Swagel, P. (2006). The politics and economics of offshore outsourcing. *Journal of Monetary Economics*, 53(5):1027–1056.

Matsuyama, K. (1992). Agricultural productivity, comparative advantage, and economic growth. *Journal of Economic Theory*, 58(2):317–334.

Matsuyama, K. (2009). Structural Change in an Interdependent World: A Global View of Manufacturing Decline. *Journal of the European Economic Association*, 7(2-3):478–486.

Melitz, M. J. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica*, 71(6):1695–1725.

Menezes-Filho, N. A. and Muendler, M.-A. (2011). Labor Reallocation in Response to Trade Reform. NBER Working Papers 17372, National Bureau of Economic Research, Inc.

Nelson, R. B. (2006). *An Introduction to Copulas*.

Ngai, L. R. and Pissarides, C. A. (2007). Structural Change in a Multisector Model of Growth. *American Economic Review*, 97(1):429–443.

Nordas, H. K. (2010). Trade in Goods and Services: Two sides of the same coin? *Economic Modelling*, 27(2):496–506.

Park, S.-C. (2002). Measuring Tariff Equivalents in Cross-Border Trade in Services. Working Paper 02-15, Korea Institute for International Economic Policy.

Perla, J., Tonetti, C., and Waugh, M. E. (2012). Equilibrium Technology Diffusion, Trade and Growth. Working paper, New York University.

Peterson, J., Pham, S., and Wohl, I. (2011). ecent Trends in U.S. Services Trade - 2011 Annual Report. Publication 4243, U.S. International Trade Commission.

Pierce, J. R. and Schott, P. K. (2014). The Surprisingly Swift Decline of U.S. Manufacturing Employment. Technical report.

Proudman, J. and Redding, S. (2000). Evolving Patterns of International Trade. *Review of International Economics*, 8(3):373–396.

Samuelson, P. A. (2004). Where Ricardo and Mill Rebut and Confimrm Arguments of Mainstream Economists Supporting Globalization. *Journal of Economic Perspectives*, 18(3):135–146.

Segerstrom, P. S. and Sugita, Y. (2013). The Impact of Trade Liberalization on Industrial Productivity. Technical report.

Shikher, S. (2012). Putting Industries into the Eaton-Kortum Model. *Journal of International Trade and Economic Development*, 21(6):807–837.

Timmer, M. (2012). The World Input-Output Databse (WIOD): Contents, Sources and Methods. Manual, University of Groningen.

Tombe, T. and Winter, J. (2012). Internal Trade and Aggregate Productivity. Meeting Papers 314, Society for Economic Dynamics.

Trefler, D. (2004). The Long and Short of the Canada-U. S. Free Trade Agreement. *American Economic Review*, 94(4):870–895.

van Leeuwen, N. and Lejour, A. (2006). Bilateral Services Trade Data and the GTAP Database. Memorandum 160, CPB.

Walsh, K. (2006). Trade in Services: Does Gravity Hold? A Gravity Model Approach to Estimating Barriers to Services Trade. Discussion Paper 183, IIIS.

Waugh, M. and Lagakos, D. (2009). Specialization, Economic Development and Aggregate Productivity Differences. Technical report.

Waugh, M. E. (2010). International Trade and Income Differences. *American Economic Review*, 100(5):2093–2124.

Yi, K.-M. and Zhang, J. (2010). Structural Change in an Open Economy. Working Papers 595, Research Seminar in International Economics, University of Michigan.

Vita

Yesheng Guo

Statistical Modeler, LexisNexis Risk Solutions
678.694.6570, Yesheng.Guo@LexisNexis.com

DOB: 12/28/86.
Citizenship: China.
Languages: English, Mandarin Chinese.

Experience

Statistical Modeler Since 05/11/15
LexisNexis Risk Solutions Inc. Alpharetta, GA

Recommend analytic solutions for insurance business.
Provide technical support to internal and external modelers.

Teaching Assistant 8/23/10 - 5/10/15
Department of Economics, Penn State University University Park, PA

Assisted administration and teaching of various undergraduate courses.

Sales Intern 07/14/08 - 08/29/08
American Depository Receipts, Bank of New York Mellon Shanghai, China

Analyzed trading performance of existing ADR programs.
Maintained existing client connections and identified business prospects.

Education

Ph.D. Economics, Penn State University May 2017

Research: Trade, Technological Convergence, Structural Transformation.
Thesis: Essays on International Trade and Structural Transformation.
Advisor: Jim Tybout.

B.S. Applied Mathematics, National University of Singapore May 2010

Field: Quantitative Finance.
Thesis: Portfolio Selection with Stochastic Volatility.
Advisor: Min Dai.