Trade and Structural Transformation: A Quantitative Analysis for China

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Abstract

How does openness in international trade affect structural transformation of an economy? How do trade policies alter the sectoral compositions of output and employment? We answer these questions by calibrating an open-economy, three-sector, structural transformation model to China during the period 1984–2012, when China expanded their trade volume in manufacturing goods rapidly. The standard, three-sector model, with non-homothetic preferences for households and differential TFP growth across three sectors, fits to the China's data well, once it is extended to the open economy environment. We use the calibrated model to run two counter-factual experiments, and quantify; 1) the effects of international trade on China's structural transformation, and 2) the effects of a tariff on China's manufacturing good export due to a trade dispute between China and the U.S. The results of the two experiments indicate that international trade plays an important role to account for changes in the sectoral compositions of China's and the rest of the world's economies.

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1 Introduction

Since the 1980s, China has been achieving the most impressive economic growth in the world, with an average annual growth rate of 9.7%. As the country grows, China has also experienced a significant change in sectoral shares among the agriculture, manufacturing and service sectors (structural transformation). The pattern of China's structural transformation is, however, at odd when compared to other countries. For most developed countries, the sectoral share generally shifts from agricultural to manufacturing and eventually to the service sector, while, as shown in the left panel of Figure 1, this is not the case for China: The sectoral shares for manufacturing have been sustainably high since 1980s. Why has China been experiencing the continuing high share of its manufacturing sector? Is there any driving force that is special for the Chinese economy?

The key to answer those questions can be found in the trade patterns of China. Within the period of 1984–2012, the export flows for manufacturing goods increased rapidly for China, as shown in Figure 1. These patterns of China's trade flow give us an idea that the structural transformation in China can be partly driven by international trade with the rest of the world. Given the radical changes in the export flows, the consistently high share in the manufacturing sector poses the question of how much trading has contributed to this high share. Therefore, further study is required to explain the possible relation between the persistent sectoral share and radical change of trade flows happening in Chinese manufacturing sector.

In this paper, therefore, we study a structural transformation model in an open economy environment to analyze the driving forces of China's recent changes in sectoral shares. Similar to the model form Uy, Yi, and Zhang (2013), we consider an economy that consists of two countries: China and the Rest of the World. Each economy is further classified into three-sectors: agricultural, manufacturing and service sector while only agricultural and manufacturing goods are tradable across countries. In this model, we incorporate non-homothetic preference in the household preference via the subsistence requirements for consumption in the household's utility function. We also assume the differential growth rates for sectoral TFP are based on data, which are channeled to the sectoral share through the price of the sectoral composite good. In terms of open economy settings, following Uy, Yi, and Zhang (2013), our model follows Ricardian trade and assumes balanced trade flows for every period.

We then estimate the model, by targeting the sectoral expenditure share and sectoral import share for both countries. The secotral expenditure share is expressed in terms of preference parameters and total consumption expenditure from data following the "partial equilibrium" approach by Herrendorf, Rogerson, and Valentinyi (2013). Turing to the sec-

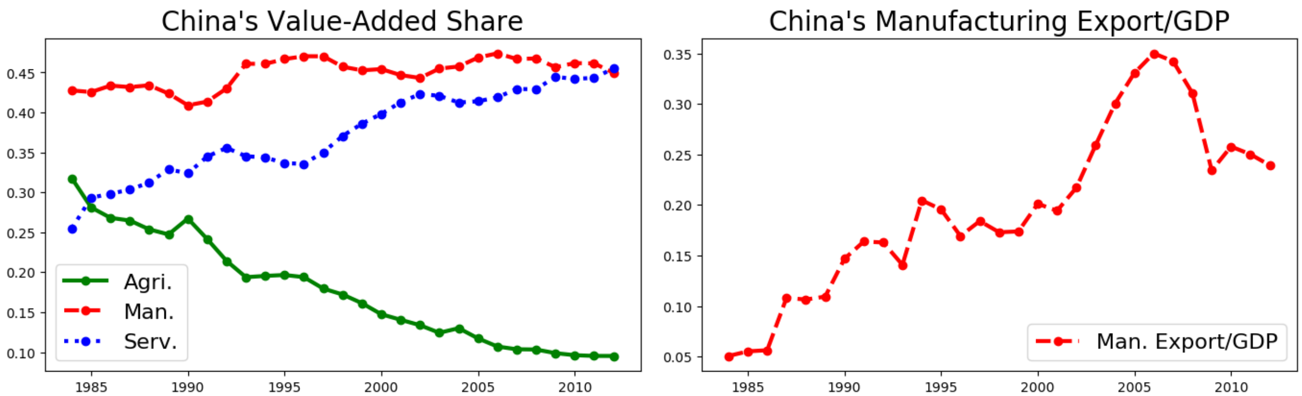

FIGURE 1 – China's Sectoral Value-Added Shares and Manufacturing Export over GDP

toral import share, it includes the parameters for estimating the model-implied trade cost. This trade cost accounts for all possibles costs within the process of trading like tariff and quotas. After we derive formulas for the model-implied sectoral expenditure share and import share, we minimize the difference between these model-implied shares with the data using non linear least square method and estimate the parameters at the same time. In result, under an open economy setting, our structural transformation model is able to fit the expenditure shares and trade flows with data quite well.

After the estimation, we quantify the effects of international trade on structural transformation by running two counter-factual experiments. In the first experiment, we shut down China's international trade with the rest of the world completely by assuming a closed economy environment. We then examine to what extent international trade had effects on the changes in the sectoral compositions of output and employment in China over the past. In the second experiment, we introduce a tariff on China's manufacturing good export, considering a situation of a trade dispute between China and the U.S. We analyze the effects of such a trade barrier on the sectoral composition of China as well as that of the rest of the world.

2 Literature Review

This paper contributes to literature in studying structural transformation with Chinese data in an open economy setting.

2.1 Structural Transformation

There have been large studies on the driving forces of the structural transformation. Herrendorf, Rogerson, and Valentinyi (2014) demonstrates how to define a sector when explaining the structural transformation. The two distinct ways are value-added approach and final expenditure approach. The authors compare these two approaches with a three-sector model and find that both approaches are consistent with data if suitable utility functions are employed. Most importantly, it introduces the strategy to study structural transformation with a three-sector model quantitatively and the procedures of extracting the driving force of the structural transformation. Following this paper, we employ a similar final expenditure approach to study structural transformation.

The two traditional explanations for structural transformation are sector-biased technological progress and non-homothetic preferences. Ngai and Pissarides (2007) starts with defining the two essential terminologies for studying structural transformation: structural change and aggregate balanced growth. As usual, structural change indicates the shifts in labour share on sectoral level. And, in equilibrium, the economy undergoing structural change with aggregate output, consumption and capital grow at the same rate is known as aggregate balanced growth path. Under some weak restrictions on utility function forms that are frequently imposed, the paper claims that structural change depends on the difference between the secotrs' TFP growth rates and the elasticity of substitution between goods. Once the economy reaches the aggregate balanced growth path, their model found that employment generally shifts away from the sectors with high rate of technological progress towards to the low growth one. In limit, the economy collapses to only two sectors with one producing capital good and the other one with lowest rate of productivity growth.

Kongsamut, Rebelo, and Xie (2001) presents a model that reconciles structural transformation with the Kaldor facts and Kuznets facts. In other words, even with the growth rate of output, capital-output ratio, real interest rate and labour income share remaining constant overtime, it is possible to model the reallocation process that the share of employment gradually shifts from the agricultural to the service sector. In their model, the differential in income elasticity of sectoral demand is the main force driving the labour reallocation across sectors . Additionally, they put some restrictions on several parameters to define a generalized balanced growth path that reconcile the Kaldor facts and Kuznets facts. Based on these studies, our model incorporates the non-homothetic preferences for household that induce differential in income elasticity of sectoral demand and the total factor productivity as the two main driving forces for structural transformation.

Furthermore, Buera and Kaboski (2009) explores structural change technically by demonstrating the shortcomings of the traditional explanations of structural change. When they evaluate them with standard neoclassical growth model using the US data. The model shows that, when only incorporating these two features, the model may fail to match the sharp increase in service and decline in manufacturing after 1960. Hence, the deficiency of the traditional model calls for more explanations that can be incorporated in the model to fit the data better. One of the deficiencies is that most previous works on structural transformation consider a closed economy setting. This leads to an incomprehensive result which ignores the potential impact from international trade.

2.2 Structural Transformation in an Open Economy

Recently, more studies on structural transformation start to look from an open economy perspective. Święcki (2017) evaluates the four mechanisms that affect the pattern of structural change under an open economy setting. To perform the evaluation, a model that combining the four mechanisms is examined with data from 45 countries over 1970-2005. Given the estimated results, the author implement counterfactual simulations to assess the relative importance of each mechanism. These four mechanisms include sector-biased productivity growth, non-homothetic preferences, international trade and changing wedges between factor costs across sectors. Consistent with the previous studies, the sector-biased productivity growth accounts for most of structural change, especially for the movement of labor from manufacturing to service. The importance of non-homothetic preferences lies in assuring the model is not overstating the productivity differences and growth in agriculture over time. However, the impact of international trade varies on countries which requires individual assessment for different countries.

Uy, Yi, and Zhang (2013) focuses on how international trade and non-homotheic preferences affect the structural transformation in a two-country case. They employ a mulit-sector model in an open economy to account for the trade cost shocks and comparative advantage in the agriculture, manufacturing and service sectors. Their model is able to fit the model-implied structural change with the South Korean data. Thereafter, they also apply a series of counterfactual simulations to examine the quantitative influence of non-homothetic preference, trade cost shocks and TFP shocks. It turns out that trade shocks have significant effect on transformations in tradable sectors while TFP shocks are significant in all sectors.

With a similar open economy setting to Uy, Yi, and Zhang (2013), Kehoe, Ruhl, and Steinberg (forthcoming)'s paper intends to examine how does international trade affect the structural change for goods, services and construction sectors in the U.S. from 1992 to 2012 Instead, they focuses on the trade deficits rather than trade costs since their model accounts for the trade imbalances by incorporating saving glut to their model as an exogenous driving force. Nevertheless, labor productivity growth rates are the most significant factors for structural change in long run while the saving glut speeds up the changes. Moreover, the saving glut changes the economy's long-run trajectory in the U.S. case. These papers show that studying the structural transformation under an open economy setting delivers more insights on the influence from trade. In this sense, our model closely follows the Uy, Yi, and Zhang (2013) paper to study the structural transformation of China in an open economy setting.

2.3 China's Structural Transformation

Turning to the Chinese economy, several papers have studied the structural transformation for China. Dekle and Vandenbroucke (2012) studies the driving forces of structural change between three sectors: agricultural sector, non-agricultural private sector and non-agricultural public sector. Their results show that the two main driving forces are the expansion of the non-agricultural public sector and the high technological progress in the private non-agricultural sector. Specifically, the expansion of the non-agricultural public sector from 1970s to 1990s absorbed labour from agriculture sector. Meanwhile, the private non-agricultural sector with higher technological progress lowers relatively price which leads to a lower demand of labour. These findings are consistent with the paper by Cheremukhin, Golosov, Guriev, and Tsyvinski (2015) which only studies agriculture and non-agriculture sector from 1953 to 2012.

With similar model settings, Brandt and Zhu (2010) studies the rate of capital investment and differential TFP growth across sectors as the driving forces. By assuming a constant aggregate investment rate, they show that China achieves the same growth performance in the absence of distortion in the capital market. This highlighted the importance of allocating resources to the efficient sectors with higher TFP levels. One of the relevant evidence from the paper is that the misallocation of capital to the state sector lead to a reduction in aggregate labor productivity growth rate.

From a different perspective, Brandt, Rawski, Sutton, et al. (2008) relates the recent market reform of the Chinese industry to the China's industrial transformation. They pointed out the key force is opening the market to induce competitions with less controls. Competition pushes the industry participators to enhance factor of productivity for staying in the market. The situation is further intensified when the government removes the barriers of trade in the trend of globalization. Therefore, apart from liberalization of the market, official policy also played a crucial role to the recent transformation in China's manufacturing sector.

Besides, there are papers focus on how does the transformation contribute to China's economic growth. For instance, Brandt, Hsieh, and Zhu (2008) quantifies the contributions of the structural transformation of the China's economy from 1978 to 2004. One of the transformation is the reallocation of labour from the agricultural to non-agricultural sector. The authors showed this reallocation is positively correlated with the overall economic growth. Consistent with the previous studies, they also find that sectoral TFP growth, labour market distortions and change in investment rate are the three main factors that influenced the reallocation in this period.

So far, most studies for China are related to the causes and contributions of structural transformation in a closed economy. On the contrary, this is the first paper aims at studying the structural transformation under an open economy setting for China with a three-sector model which includes agriculture, manufacturing and service.

3 Model

Our objective is, through the lens of a three-sector model with two countries, to analyze the change in sectoral shares during China's recent economic development. This section considers a three-sector model (agricultural (a), manufacturing (m) and service (s)) following the model by Uy, Yi, and Zhang (2013) in which only agricultural and manufacturing are tradable sectors. There is a representative household in each country who can consume good from each sector to maximize his utility. For the production side of each sector, the individual good firms use labour as factor of production. There exists trade on intermediate good that producers can purchase from either home or foreign country whichever offers a cheaper price. The trade follows Ricardian motive with a similar structure to Eaton and Kortum (2002). Then the individual goods are aggregated into composite goods using Ethier (1982) or Dixit and Stiglitz (1977) aggregator.

3.1 Setup

We consider two countries: China and the Rest of the World (ROW). In each economy, there are three sectors, agriculture (a), manufacturing (m), and service sectors (s). Each country trades a agricultural good and a manufacturing good with the other, while we assume services are not tradable. There is a representative household in each country who consumes those three goods.

3.2 Technologies

In the country i, there is a continuum of goods in each of the three sectors. The production function that describes the output of good $z \in [0,1]$ in each sector $k \in \{a, m, s\}$ is given by

$$Y_{i,t}^{k}(z) = A_{i,t}^{k}(z) \left[L_{i,t}^{k}(z)\right]^{\lambda_k} \left[\prod_{n=a,m,s} \left(M_{i,t}^{k,n}(z)\right)^{\gamma_{k,n}}\right]^{1-\lambda_k} \tag{1}$$

where $Y_{i,t}^{k}(z)$ is output, $A_{i,j}^{k}(z)$ is exogenous productivity, $L_{i,t}^{k}(z)$ is labor input, and $M_{i,t}^{k,n}(z)$ is composite sector-n goods used as intermediates in the production of the sector k good. The two parameters λ_k and $\gamma_{k,n}$ determine the value-added share and the share of intermediate from sector n in the production function, respectively. As in Eaton and Kortum (2002), we assume that, in every period, the productivity $A_{i,t}^{k}(z)$ is drawn from a Fréchet distribution: $F_{i,t}^{k}(A) = e^{-T_{i,t}^{k}A^{-\theta}}$, where $T_{i,t}^{k} > 0$ and $\theta > 1$. Thus, the sector k's mean productivity increases as $T_{i,t}^{k}$ becomes greater.We assume perfect competition in each country's goods markets. The price good z in sector k is given by $p_{i,t}^{k}(z) = \frac{v_{i,t}^{k}}{A_{i,t}^{k}(z)}$ where $v_{i,t}^{k}$ is the costs of the production given by

$$v_{i,t}^{k} = (w_{i,t})^{\lambda_k} \left(\Pi_{n=a,m,s}\left(P_{i,t}^{n}\right)^{\gamma^{k,n}}\right)^{\lambda^k}$$

where $w_{i,t}$ is the wage and $P_{i,t}^{n}$ is the price of sector-n composite goods.

In each sector k, competitive buyers buy good $Q_{i,t}^{k}(z)$ either from the domestic (country i's) or the foreign (country j's) supplier whichever can offer a lower price, $\hat{p}_{i,t}^{k}(z) = \min\left\{p_{i,t}^{k}(z), p_{j,t}^{k}(z)\right\}$. Then, the goods are bought either from the domestic or foreign supplier, $\left\{Q_{i,t}^{k}(z)\right\}_{z\in[0,1]}$, are aggregated to a composite good, $Q_{i,t}^{k}$, within country i, as

$$Q_{i,t}^{k} = \left(\int_{0}^{1} \left(Q_{i,t}^{k}(z)\right)^{\frac{\eta-1}{\eta}} dz\right)^{\frac{\eta}{\eta-1}},$$

where $\eta > 0$ governs the elasticity of substitution across goods. Shipping of goods incurs trade costs, which include tariffs, transportation costs, and other barriers to trade. In particular, we assume iceberg costs $\tau_{i,j,t}^{a}$ for shipping an agricultural good z to country i from country j. Then, $\frac{1}{\tau_{i,j,t}^{a}}$ units of the good arrive in country i. As standard in the literature, we assume that the trade costs are zero within a country, $\tau_{i,i,t}^{a} = \tau_{i,i,t}^{m} = 0$. Finally, we assume that the composite sectoral goods can be used in domestic final consumption, $C_{i,t}^{k}$, and domestic production as intermediate inputs.

3.3 Prices and Trade Shares

Eaton and Kortum (2002) shows that, under the Fréchet distribution assumption, the price of tradable composite good $k \in \{a, m\}$ in country i is $P_{i,t}^k = \Gamma \left(\Phi_{i,t}^k\right)^{-\frac{1}{\theta}}$, where the constant Γ is the Gamma function evaluated at $\left(1 - \frac{\eta-1}{\theta}\right)^{\frac{1}{1-\eta}}$, and $\Phi_{i,t}^k = T_{i,t}^k \left(v_{i,t}^k \tau_{i,i,t}^k\right)^{-\theta} + T_{j,t}^k \left(v_{j,t}^k \tau_{i,j,t}^k\right)^{-\theta}$. Thus, $\Phi_{i,t}^k$ summarizes country i's access to global production technologies in sector k scaled by the relevant unit costs fo inputs and trade costs. For the service composite good, the price is $P_{i,t}^s = \Gamma \left(\Phi_{i,t}^s\right)^{-\frac{1}{\theta}}$, where $\Phi_{i,t}^k = T_{i,t}^k \left(v_{i,t}^k\right)^{-\theta}$. To ensure a well-defined price index, we assume $\eta - 1 < \theta$ which is standard in the literature. Under this assumption, the parameter η, which governs the elasticity of substitution across goods within a sector, can be ignored because it appears only in the constant term Γ.

Eaton and Kortum (2002) also shows that, under the Fréchet distribution assumption, we can derive the the share of country j's expenditure on sector-k goods from country i, as

$$\pi_{j,i,t}^k = \frac{T_{i,t}^k \left(v_{i,t}^k \tau_{i,i,t}^k\right)^{-\theta}}{\Phi_{j,t}^k}, \tag{2}$$

which equals the probability of importing sector-k goods from country i in country j. Thus, country j's share of imports in the total expenditure depends on country i's average productivity, the cost of the input bundle, and the trade costs to ship goods from country i to country j.

3.4 Household

The representative household in country i maximizes his own utility with non-homothetic preference following

$$U\left(C_{i,t}^a, C_{i,t}^s, C_{i,s}^m\right) = \left(\sum_{k=a,m,s} \left(\omega^k\right)^{\frac{1}{\sigma}} \left(C_{i,t}^k + \overline{C}^k\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}. \tag{3}$$

where $C_{i,t}^k$ is the consumption of sector-k composite goods for $k \in a, m, s$. The non-homotheic preference is introduced by $\overline{C}^k$ which is the subsistence consumption for sector-k composite goods. When $\overline{C}^k$ has a non-zero value, the household no longer has a constant income elasticity of demand for the sector-k goods. And the income elasticity of demand now varies with the value of $\overline{C}^k$.

The maximization is subjected to the following budget constraint

$$P_{i,t}^a C_{i,t}^a + P_{i,t}^m C_{i,t}^m + P_{i,t}^s C_{i,t}^s = w_{i,t} \tag{4}$$

where $w_{i,t}$ is the household's wage rate from supplying his unit labour inelastically and $P_{i,t}^{k}$ is the price of the sector-k composite good. For each period, the household spends all income on consumption and this ensure that the model inherits the balance trade every period.

3.5 Equilibrium

Within a country, we assume perfect competition for all the goods and factor markets. In particular, we assume labor is mobile without any cost across the three sectors. Let $L_{i,t}$ denote total labor endowment in county i, and $L_{i,t}^{k}$ labor employed in sector k. Then, the following, labor market clearing condition holds every period within the country, as

$$L_{i,t} = L_{i,t}^{a} + L_{i,t}^{m} + L_{i,t}^{s}. \tag{5}$$

The goods markets also have to be cleared every period. For each sector k, we have

$$Q_{i,t}^{k} = C_{i,t}^{k} + \sum_{n=a,m} \left(1 - \lambda^{k}\right) \gamma^{n,k} \left[\frac{\pi_{j,i,t}^{n} P_{j,t}^{n} Q_{j,t}^{n}}{P_{i,t}^{k}} + \frac{\pi_{j,i,t}^{n} P_{j,t}^{n} Q_{j,t}^{n}}{P_{i,t}^{k}}\right] + \left(1 - \lambda_{s}\right) \gamma^{s,k} \frac{P_{i,t}^{s} Q_{i,t}^{s}}{P_{i,t}^{k}}. \tag{6}$$

The above equation relates the total production of goods in sector k, $Q_{i,t}^{k}$, to the sum of the quantity demanded for domestic final production, $C_{i,t}^{k}$, for the usage of intermediate inputs in the production of domestic tradable goods, and the usage of intermediate inputs in the production of domestic service goods.

A competitive equilibrium of the model is defined given country-specific labor endowment $\{L_{i,t}\}$, trade costs $\left\{\tau_{i,j,t}^{a}, \tau_{i,j,t}^{m}\right\}$ productivity process $\left\{T_{i,t}^{a}, T_{i,t}^{m}, T_{i,t}^{s}\right\}$, and common structural parameters $\left\{\sigma, \eta, \theta, \left\{\lambda^{k}, \gamma^{k,n}, \bar{C}^{k}, \omega^{k}\right\}_{n,k \in \{a,m,s\}}\right\}$ as follows

Definition 1. *A competitive equilibrium is a sequence of goods and factor prices* $\left\{P_{i,t}^{a}, P_{i,t}^{m}, P_{i,t}^{s}, w_{i,t}\right\}_{i \in \{c,r\}}$, *allocations* $\left\{L_{i,t}^{a}, L_{i,t}^{m}, L_{i,t}^{s}, Q_{i,t}^{a}, Q_{i,t}^{m}, Q_{i,t}^{s}, C_{i,t}^{a}, C_{i,t}^{m}, C_{i,t}^{s}\right\}_{i \in \{c,r\}}$ *and trade shares* $\left\{\pi_{i,j,t}^{a}, \pi_{i,j,t}^{m}\right\}_{i,j \in \{c,r\}}$ *such that, given prices, the allocations solve the firms' maximization problems associated with technologies (1), an the household's maximization problem characterized by (3)-(4), and satisfy the market clearing conditions (5)-(6).*

3.6 Driving Forces of Structural Transformation

There are three driving forces of structural transformation in our model. First, the differential TFP growth across three sectors. This is the most common one in literature which contributes to the structural transformation via the price effect. The intuition is that higher

TFP drives down the sectoral price. In response, the labor share of particular sector shifts to other sectors which have higher prices. The other common driving force is the non-homothetic preference parameter in household's utility function. In other words, the household has a different income effect for different sectoral goods. More importantly, as shown by Uy, Yi, and Zhang (2013), calibrating the model with non-homothetic preference enhance the fit to data in both closed and open economy. Under the trend of globalization, international trade becomes increasingly significant as a driving force for structural transformation. The reason is that the availability of foreign goods has a certain influence on how does the economy react to a change in differential TFP growth and non-homothetic preference parameter in an open economy.

4 Calibration

This section describes how we map the model to the data. Firstly, we derive the sectoral expenditure shares, for which we target to estimate the underlying parameters of the model, together with import shares. We implement two-step procedure for calibration. In the initial step, the values of a set of pre-determined parameters are fixed. In the second step, we estimate the model by non-linear least squares. In particular, we minimize the difference between the model-implied, sectoral expenditure shares and the import shares and those in the data to estimate the unknown parameters. In the following section, the first part describes the formula for the expenditure shares and the import shares we used for estimation. The second part presents how we calibrate the model to the data.

4.1 Expenditure Share and Import Share

To obtain the model-implied sectoral expenditure shares, we follow the "partial equilibrium" approach from Herrendorf, Rogerson, and Valentinyi (2013). The "partial equilibrium" approach aims to maximize the household utility for each period and bypass the complexity from the intertemporal interest available to the household. Given this approach, by assuming an interior solutions for the household problem, we find the first-order conditions and express the model-implied expenditure share as follows

$$s_{i,t}^{k} = \frac{\omega^{k}\left(P_{i,t}^{k}\right)^{1-\sigma}}{\sum_{l=a,m,s}\omega^{l}\left(P_{i,t}^{l}\right)^{1-\sigma}}\left(1-\sum_{l=a,m,s}\frac{P_{i,t}^{l}\overline{C}^{l}}{P_{i,t}C_{i,t}}\right)+\frac{P_{i,t}^{k}\overline{C}^{k}}{P_{i,t}C_{i,t}}.$$

This formula expresses the sectoral expenditure share in terms of the price of sectoral-k good $P_{i,t}^{k}$ and the total consumption expenditure with parameters from the household's utility

Table 1 – Pre-Determined Parameters

Pre-Determined Parameters		Value	Source
θ	Shape parameter for the Fréchet distribution	4	Uy, Yi, and Zhang (2013)
η	Elasticity of substitution across goods within a sector	4	Uy, Yi, and Zhang (2013)
λ^a	Value-added share for agriculture	0.456	Uy, Yi, and Zhang (2013)
λ^m	Value-added share for manufacturing	0.275	Uy, Yi, and Zhang (2013)
λ^s	Value-added share for service	0.576	Uy, Yi, and Zhang (2013)
$\bar{C}^m$	Subsistence requirement	0	Herrendorf, Rogerson, and Valentinyi (2013)

function. The price of sectoral-k good $P^k_{i,t}$ is determined by the price formula mentioned in the model section. With the data of total consumption expenditure, we can estimate the set of unknown parameters from the household's utility function.

When mapping the model to the data, we also use the import share that allows us to estimate the trade costs. Intuitively, the import share is governed by the productivity, input cost and trade cost. This can be seen from the model-implied import share formulation which is

$$\pi^k_{i,j,t} = \frac{T^k_{j,t}\left(v^k_{j,t}\tau^k_{i,j,t}\right)^{-\theta}}{T^k_{i,t}\left(v^k_{i,t}\tau^k_{ii,t}\right)^{-\theta} + T^k_{j,t}\left(v^k_{j,t}\tau^k_{i,j,t}\right)^{-\theta}}.$$

We can solve for this import share given the value of parameter θ, the underlying TFP $T^k_{i,t}$ from the data, the input cost, $v^k_{j,t}$ and the trade cost, $\tau^k_{i,j,t}$. The trade cost $\tau^k_{i,j,t}$ follows an exponential function consists of a constant parameter α^k_i and a time trend β^k_i as

$$\tau^k_{i,j,t} = \exp(\alpha + \beta^k_i t)$$

where t denotes the time period. With exponential function, we ensure the trade cost is non-negative for both countries.

4.2 Non-Linear Least Square

Following the two-step procedure, we start with discussing the values of the set of pre-determined parameters. They are the shape parameter for Fréchet distribution, the elasticity of substitution across goods within a sector, the value-added share for three sectors and the subsistence requirement for the manufacturing sector. The values of those parameters are listed in Table 1. The parameter values are either borrowed from Uy, Yi, and Zhang (2013) or Herrendorf, Rogerson, and Valentinyi (2013).

Since the expenditure share and import share formulas contain the sectoral-k good price $P^k_{i,t}$ and input cost $v^k_{i,t}$ which are unknown variables, we first solve the values of both variables by iterating them. Given the set of the pre-determined parameters, the TFPs of the three

Table 2 – Parameters to be Estimated

Parameters to be Estimate	
ω^a	Weight on agricultural good
ω^m	Weight on manufacturing good
ω_s	Weight on service good
$\overline{C}^a$	Subsistence requirement for agricultural good
$\overline{C}^s$	Subsistence requirement for service good
σ	Elasticity of substitution
$\{\alpha_i^a\}_{i\in\{c,r\}}$	Initial level of trade cost
$\{\alpha_i^m\}_{i\in\{c,r\}}$	Initial level of trade cost
$\{\beta_i^a\}_{i\in\{c,r\}}$	Trend of trade cost
$\{\beta_i^m\}_{i\in\{c,r\}}$	Trend of trade cost

sectors in each country, $\left\{T_{i,t}^k\right\}$, as we describe in detail in Appendix A, we compute the sectoral expenditure shares and the import shares, and estimate the set of the rest of the parameters via non-linear least square with a system of equations as follow

$$\hat{s}_{i,t}^k = s_{i,t}^k + \epsilon_{i,t}^k,$$
$$\hat{\pi}_{i,j,t}^k = \pi_{i,j,t}^k + \nu_{i,t}^k,$$

where $\left\{\epsilon_{i,t}^k, \nu_{i,t}^k\right\}$ are measurement errors associated with expenditure shares and import shares. In the above system of the equations, $\left\{\hat{s}_{i,t}^k\right\}$ and $\left\{\hat{\pi}_{i,j,t}^k\right\}$ are the expenditure shares and import shares computed from the data respectively. With this system of equations, it includes two equations for the expenditure shares and two equations for import shares. In terms of expenditure shares, as long as the summation of expenditure shares across three sectors is equal to one, we can easily infer the expenditure share for the third sector without using the non-linear least square method. In our case, we include the expenditure shares of the agriculture and manufacturing sector and compute the share of service sector based on the estimated values from the non-linear least square. For the import shares, since service good is nontradable, we only have to include agriculture and manufacturing import shares for both countries in the system. In total, the system have eight equations with fourteen parameters. The results of this system of equation are listed in Table 2.

5 Data

In this section, we discuss how we construct the data for both China and ROW from 1984 to 2012. We obtain the data from four different databases including the "China Statistical

Yearbooks", "COMTRADE Database", "National Accounts Main Aggregates Database" and "GGDC 10-sector Database".

Due to the data limitation, we assume the ROW to be the top twenty trading partners with China. The data for these twenty countries mainly comes from "National Accounts Main Aggregates Database" and "GGDC 10-sector Database". Following Dekle and Vandenbroucke (2012), our data for China comes from the annual issue of "China Statistical Yearbooks"(CSY) which is the official economic statistics source for China. The reliability of the CSY has always been questioned due to its methodology for recording the data. Nevertheless, given CSY is the most up-to-date and comprehensive data source for China, we employ it with cautious modifications if necessary.

For the purpose of our estimation, we compute the total factor productivity (TFP), wage and total consumption expenditure, and import share for China and ROW from the data. These variables are divided into three sectors: agriculture, manufacturing and service. Unlike the common database, the CSY only provides data in three strata of industry instead of detailed categories of goods. The definitions of the strata are brief and the classification is not implemented according to standard classification protocol. On the other hand, the data from "National Accounts Main Aggregates Database" and "GGDC 10-sector Database" is predetermined according to the the classification of ISIC Rev. 3.1. To ensure data consistency, we define the three sectors in our model based on the ISIC Rev. 3.1 while closely follow the definition of strata available in CSY. Lastly, the "COMTRADE Database" reports the bilateral trade flows between chosen countries in categories of goods.

5.1 Total Factor Productivity by Sector

The computation of measured TFP employs the real value-added data and employment data. The CSY gives the number of employed persons at year-end and the nominal gross domestic product for China. As mentioned above, our three board sectors are defined according to the three strata of industry. This allows us to implement the data with no further modification when classifying the sectors. To recover the real GDP from the nominal GDP, we followed the method suggested by Young (2003). This paper points out that, when deflating the nominal GDP, the survey based price indices are superior instrument comparing to the implicit GDP deflators from the CSY. Specifically, we deflated the nominal GDP of primary, secondary and the tertiary sectors by the general price index of farm product, ex-factory industrial price index and service price index respectively.

On the other hand, the number of employed persons at year-end for ROW is obtained from the "GGDC 10-sector Database". Unlike the data for China, both nominal and real

GDP for the ROW is available in "National Accounts Main Aggregates Database" and we compute the measured TFP with these data for the ROW. To implement these data, we classify them into three sectors according to the method mentioned.

5.2 Wages by Sector

Similar to the TFP by sector, the wage consists of real value-added data and employment data. The difference lies in the formulation which allows us to employ the same data from the above with the same sector classification.

5.3 Trade Flows by Sector

The trade data from the "COMTRADE Database" is available in categories of goods. We start with classifying the trade data into three sectors following the same classification procedure. Then, we aggregate these separate bilateral trade data between China and the top twenty trading partners as the ROW. In this procedure, we select China as the "reporter" and the ROW as the "partner" when we downloaded the data. Finally, since the value of import for China is equivalent to the value of export for ROW, we have the import and export data for both countries from a single computation.

5.4 Total Consumption Expenditure by Sector

Since the total factor productivity is constructed with real GDP, we measure the sectoral total consumption expenditure for China and ROW in real term. Firstly, the "COMTRADE Database" only provides the trade flow data in current value. To convert these trade data into real terms, we construct the deflator by dividing the nominal GDP with the real GDP computed above. After deflating the trade data, we deduce the total value export from the real gross domestic product and adding the total value import to get total consumption expenditure. For the sectoral total consumption expendiure, we follow the same procedure but classify the data into sectors beforehand.

Finally, for the TFPs and wages, we adjust them so that they have consistent definitions with those in the model. The details of the adjustments are discussed in Appnedix (B).

6 Results

In this section, we describe the result of the estimation and how does it responds to counterfactual experiments. We start with reporting the parameter values from calibration. With

Table 3 – The Estimated Values of the Parameters

Estimated Parameters		Value for China	Value for ROW
ω^a	Weight on agricultural good	1.0858	
ω^m	Weight on manufacturing good	5.2989	
ω_s	Weight on service good	13.9767	
$\overline{C}^a$	Subsistence requirement for agricultural good	5.7208e+10	
$\overline{C}^s$	Subsistence requirement for service good	-2.1295e+11	
σ	Elasticity of substitution	1.3912	
$\{\alpha_i^a\}_{i\in\{c,r\}}$	Initial level of trade cost	1.5607	3.5205
$\{\alpha_i^m\}_{i\in\{c,r\}}$	Initial level of trade cost	-0.3734	1.8336
$\{\beta_i^a\}_{i\in\{c,r\}}$	Trend of trade cost	0.0320	-0.1451
$\{\beta_i^m\}_{i\in\{c,r\}}$	Trend of trade cost	-0.0526	0.0217

these parameter values in hand, we proceed to counterfactual experiments to evaluate how the model-implied sectoral expenditure share change under a closed economy and an open economy with no TFP change in China's manufacturing sector.

6.1 Estimated Results

Table 3 provides the values for the estimated parameters from our benchmark model. Based on the results, there are several estimated parameters are worthy of further explanation. Starting with the preference share parameters $\left\{\omega^k\right\}$, without the constraint of summing up to one across sectors, the value are positive as expected since this implies that individual has positive utility by consuming goods from each sector. In accordance to Herrendorf, Rogerson, and Valentinyi (2013), we assume the income elasticity of demand for manufacturing sector is close to one by setting $\bar{C}_m$ equals to zero and estimate $\bar{C}_a$ and $\bar{C}_m$. The estimate of the $\bar{C}_a$ is positive while negative for $\bar{C}_s$. In this case, the individual first achieves the subsistence consumption on agriculture goods and then on manufacturing goods. The remaining rest will be allocated to the service goods.

The main goal is to minimize the difference between the model-implied sectoral expenditure share and the actual expenditure share as well as the difference between the model implied sectoral import share and the actual sectoral import share. Table 4 compares the result of the shares of each sector for both countries in 1984 and 2012. It shows that the model-implied sectoral shares for the initial and last year of our studied time period are consistent with data when the largest difference between the model-implied and actual share is below 0.08 across all sectors except for the import share of manufacturing in China.

Table 4 – Estimation Results

			China		ROW	
			Model	Data	Model	Data
Expenditure Share	1984	Agriculture	0.3551	0.3092	0.0543	0.0497
		Manufacturing	0.4684	0.4411	0.2994	0.3540
		Service	0.2497	0.1765	0.6462	0.5963
	2012	Agriculture	0.0269	0.0980	0.0534	0.0262
		Manufacturing	0.4712	0.4322	0.3024	0.2618
		Service	0.5018	0.4698	0.6442	0.7119
Import Share	1984	Agriculture	0.0228	0.0005	0.0000	0.0023
		Manufacturing	0.1159	0.1624	0.0245	0.0055
	2012	Agriculture	0.0321	0.0280	0.0218	0.0122
		Manufacturing	0.2732	0.4974	0.2168	0.1205

7 Counterfactual Experiment

To be added.

8 Conclusion

To be added.

References

Brandt, L., C.-T. Hsieh, and X. Zhu (2008): "Growth and Structural Transformation in China," in *China's Great Economic Transformation*, pp. 683–728.

Brandt, L., T. G. Rawski, J. Sutton, et al. (2008): "China's Industrial Development," in *China's Great Economic Transformation*, pp. 569–632.

Brandt, L., and X. Zhu (2010): "Accounting for China's Growth," *Working Paper*.

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

Cheremukhin, A., M. Golosov, S. Guriev, and A. Tsyvinski (2015): "The Economy of People's Republic of China from 1953," *Working Paper*.

Dekle, R., and G. Vandenbroucke (2012): "A Quantitative Analysis of China's Structural Transformation," *Journal of Economic Dynamics and Control*, 36(1), 119–135.

Dixit, A. K., and J. E. Stiglitz (1977): "Monopolistic Competition and Optimum Product Diversity," *The American Economic Review*, 67(3), 297–308.

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

Ethier, W. J. (1982): "National and International Returns to Scale in the Modern Theory of International Trade," *The American Economic Review*, 72(3), 389–405.

Herrendorf, B., R. Rogerson, and A. Valentinyi (2013): "Two Perspectives on Preferences and Structural Transformation," *The American Economic Review*, 103(7), 2752–2789.

Herrendorf, B., R. Rogerson, and Á. Valentinyi (2014): "Growth and Structural Transformation," *Handbook of Economic Growth*, 2, 855–941.

Kehoe, T. J., K. J. Ruhl, and J. B. Steinberg (forthcoming): "Global Imbalances and Structural Change in the United States," *Journal of Political Economy*.

Kongsamut, P., S. Rebelo, and D. Xie (2001): "Beyond Balanced Growth," *The Review of Economic Studies*, 68(4), 869–882.

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

Święcki, T. (2017): "Determinants of Structural Change," *Review of Economic Dynamics*, 24, 95–131.

Uy, T., K.-M. Yi, and J. Zhang (2013): "Structural Change in an Open Economy," *Journal of Monetary Economics*, 60(6), 667–682.

Young, A. (2003): "Gold into Base Metals: Productivity Growth in the People's Republic of China During the Reform Period," *Journal of political economy*, 111(6), 1220–1261.

Appendix

A Computation and Estimation of the Model

This appendix explains how we compute and estimate the model. The parameters to be estimated are:

$$\Theta = \left\{\omega^a, \omega^m, \omega^s, \overline{C}^a, \overline{C}^s, \sigma, \{\alpha_i^a, \alpha_i^m, \beta_i^a, \beta_i^m\}_{i\in\{c,r\}}\right\}$$

where $\{\alpha_i^a, \alpha_i^m, \beta_i^a, \beta_i^m\}_{i\in\{c,r\}}$ determine the trade costs as

$$\tau_{i,j,t}^k = \alpha_i^k + \beta_i^k t.$$

In the estimation process, we solve the model given those parameter values. The steps of the computation of the model is summarized as follows:

1. Given the set of the parameters, find the prices by iterating the following formulas for the sector $k \in \{a, m\}$:

$$\begin{aligned} v_{i,t}^k =& w_{i,t}^{\lambda_k} \left(\Pi_{n=a,m,s} \left(P_{i,t}^n\right)^{\gamma_{k,n}}\right)^{1-\lambda_k}, \\ P_{i,t}^k =& \Gamma \left(T_{i,t}^k \left(v_{i,t}^k \tau_{i,i,t}^k\right)^{-\theta} + T_{j,t}^k \left(v_{j,t}^k \tau_{i,j,t}^k\right)^{-\theta}\right)^{-\frac{1}{\theta}}. \end{aligned}$$

2. For the service sector, the price is given by

$$P_{i,t}^s = \Gamma \left(T_{i,t}^s \left(v_{i,t}^s \tau_{i,i,t}^s\right)^{-\theta}\right)^{-\frac{1}{\theta}}.$$

   where $\tau_{i,i,t}^s = 1$.

3. Calculate the import share of country j's good in country i's sector k:

$$\pi_{i,j,t}^k = \frac{T_{j,t}^k \left(v_{j,t}^k \tau_{i,j,t}^k\right)^{-\theta}}{T_{i,t}^k \left(v_{i,t}^k \tau_{ii,t}^k\right)^{-\theta} + T_{j,t}^k \left(v_{j,t}^k \tau_{i,j,t}^k\right)^{-\theta}}.$$

4. Calculate the sectoral shares, $\left\{s_{i,t}^k\right\}_{l=a,m,s}$

$$s_{i,t}^k = \frac{\omega^k \left(P_{i,t}^k\right)^{1-\sigma}}{\sum_{l=a,m,s} \omega^l \left(P_{i,t}^l\right)^{1-\sigma}} \left(1 - \sum_{l=a,m,s} \frac{P_{i,t}^l \overline{C}^l}{P_{i,t} C_{i,t}}\right) + \frac{P_{i,t}^k \overline{C}^k}{P_{i,t} C_{i,t}},$$

   where $P_{i,t}C_{i,t}$ is the total expenditure defined in the data.

5. We use the nonlinear least square as

$$\begin{aligned} \hat{s}_{i,t}^k &= s_{i,t}^k + \epsilon_{i,t}^k \\ \hat{\pi}_{i,j,t}^k &= \pi_{i,j,t}^k + \nu_{i,t}^k \end{aligned}$$

where $\left\{\hat{s}_{i,t}^k\right\}$ and $\left\{\hat{\pi}_{i,j,t}^k\right\}$ are from the data.

When estimating the model, we repeat the step 1–4 to evaluate the expenditure shares and the import shares for a diffent set of the parameter values.

B Measuring the TFPs and Wages

In this appendix, we describe how we compute the TFPs and wages, $\left\{T_{i,t}^{k}, w_{i,t}\right\}$, used for our estimation. The following three steps describe the procedure.

1. We first computed the measured TFP based on the value-added production function. This value-added production derived from the gross production (1) as follows

$$\lambda^{k}\left(P_{i,t}^{k}\right)^{\frac{1}{\lambda_{k}}}\left[\left(1-\lambda^{k}\right)\prod_{n=a,m,s}\left(\frac{\gamma^{k,n}}{P_{i,t}^{n}}\right)^{\gamma^{k,n}}\right]^{\frac{1-\lambda^{k}}{\lambda^{k}}}\left(A_{i}^{k}\right)^{\frac{1}{\lambda^{k}}}L_{i}^{k}.$$

   This implies that the gross output TFP can be computed using real value added and employment data as follows

$$\tilde{A}_{i,t}^{k}=\left(\frac{RVA_{i,t}^{k}}{L_{i,t}^{k}}\right)^{\lambda^{k}}.$$

2. We apply the time-series of real value-added and employment discussed above to compute the measured TFP for China and ROW. However, this measured TFP includes the effect of specialization when trading and the fundamental TFP from a closed economy setting. To isolate the fundamental TFP, we employ the method from Finicelli, Pagana and Sbracia (2012). Their paper shows that the difference between the measured TFP and fundamental TFP comes from trade share. The trade share can be accounted by the sectoral domestic absorption ratio as below

$$\pi_{i,i,t}^{k}=\frac{VA^{\mathrm{k}}-E^{k}}{VA^{k}-E^{k}+I^{\mathrm{k}}}$$

   where E^{k} and I^{k} denotes the export and import for sector k of country i. The sectoral domestic absorption ratio is equivalent to the share of consumption comes from domestic production relative to the aggregate consumption. Given this ratio, we can link the measured TFP to the fundamental TFP by

$$A_{i,t}^{k}=\left(\pi_{i,i,t}^{k}\right)^{\frac{1}{\theta}}\tilde{A}_{i,t}^{k}.$$

3. Finally, calculate the underlying TFP, $T_{i,t}^{k}$,

$$T_{i,t}^{k}=\left(\frac{A_{i,t}^{k}}{\Gamma\left(\frac{\theta-1}{\theta}\right)}\right)^{\theta}$$

   where Γ is a gamma function evaluated at $\left(1-\frac{\eta-1}{\theta}\right)^{\frac{1}{1-\eta}}$. We also calculate the wage in each country:

$$w_{i,t}=\frac{RVA_{i,t}}{L_{i,t}}.$$