Sluggish Growth or Premature Decline? A Comparative Study of Indian Industrialization with China *

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Abstract: Indian manufacturing has remained stagnant in terms of its share in value-added and employment. While India and China started their growth journeys around the same time, China underwent rapid industrialization, whereas India's manufacturing sector stagnated, and its services sector boomed. This paper uses a dynamic open economy general equilibrium model with endogenous capital accumulation and income and price effects to compare the structural transformations of India and China. The findings reveal that India's sluggish manufacturing is largely due to slow productivity growth and low investment rates. However, Indian manufacturing has not prematurely declined but has yet to take off. If India's TFP had grown at the same rate as China's, the manufacturing share would have increased by 1.5-fold, and per capita income would have risen by more than double. Export-promoting industrial policies and increased investment could drive further growth in the manufacturing sector.

Keywords: Structural Transformation, Industrialization, Productivity Growth, International Trade, Non-homothetic Preferences

JEL classification code: O4, O5, F62, F63

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1 Introduction

Since 1970, India has seen a stagnant manufacturing sector both in terms of employment share and value-added share. Like many developing countries in Latin America and Africa, it has skipped the low-skilled manufacturing stage and transitioned to the services sector. Much of the GDP growth coming from the services sector is dependent on its comparative advantage in skilled labor-intensive services, led by a scarce workforce. In contrast, it is missing out on the demographic dividends that could have been reaped from the abundant young, low-skilled labor. As a result of this, India's per-capita income (in 2017 US$ at Chained PPP) has grown from $1,430 in 1970 to $6,550 in 2019, less than five-fold in 50 years. On the other hand, China's per capita GDP in 1970 was less than India's, but it grew from $1,300 to a whopping $14,000 in the same period, more than ten-fold. Contrasting the Indian story with the neighboring manufacturing giant, China, is an exciting tale to investigate. Both countries were closed economies in 1970 and, later on, opened up for trade, and have witnessed a remarkably different structural transformation.

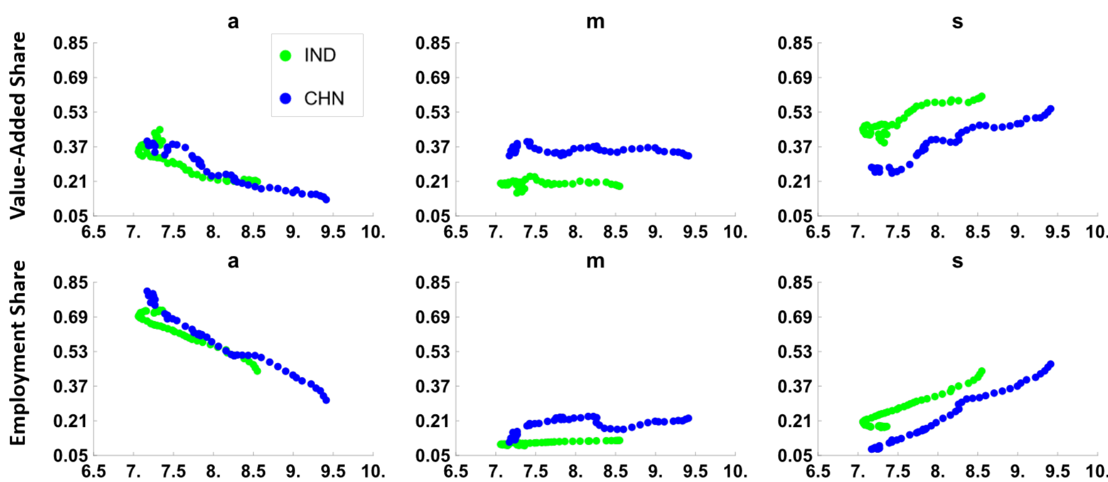

Figure 1: *Sectoral share of Value-Added share and Employment shares (y-axis) at the log of per-capita income (in 2017 US$ at chained PPP) (x-axis). Data is for the period 1970-2014.*

Figure 1 plots the share of Value-Added and employment against the per-capita income at PPP for India and China. The period covered is 1970-2014 (the same period for which the model has been quantified later). The trajectory for agriculture is pretty similar for both countries, but the manufacturing and services sectors are sharply different. The share of manufacturing in India has been substantially low at all levels of per-capita income. As income grew, there was a clear pattern of declining share of agriculture and increasing services, but there was no clear hump pattern in manufacturing in either India or China. However, the share seems to start declining in China post-2007 after reaching a peak of 36.5% at a per capita income of $8,065. So far, India has reached the manufacturing peak of 23.35% at the per-capita income of $1,682 in 1995.

Two critical questions arise at this point. One, how India and China were different, to begin with, in 1970, and what they did differently to have a transformation that they witnessed. Two, has India already seen the peak in its manufacturing, and is it a classic case of premature de-industrialization, or is it yet to experience full-fledged industrialization? I will be approaching the analysis in this paper from these two perspectives.

Traditionally, the rapid growth of the economy has been associated with a remarkable story of industrialization across the globe. However, most of the developing countries today are witnessing a rapid rise in services and a stagnancy or premature decline of their industries. Rodrik (2016) raised concerns that a lack of manufacturing delays productivity growth in low-income countries and, therefore, blocks off the main avenue of economic convergence. Also, premature deindustrialization raises informality, driving the workforce and resources toward low-productivity services. He also argues that TFP growth plays a significant role in the deindustrialization of advanced economies. In contrast, globalization and trade play a relatively more substantial role in the premature decline of industries in the developing world. Supporting Rodrik (2016)'s argument, Matsuyama and Fujiwara (2022) says that the steadily increasing gap from frontier technology is one of the critical factors causing premature deindustrialization. So, it is important to understand the role of TFP growth and international trade in the transformation stories.

Along with asymmetric productivity growth and globalization, non-homothetic preferences have been an essential tool in the structural transformation models. As income grows, the composition of the consumption basket of the households moves from less agriculture to more manufacturing and then more services, and so do the economic activities. However, much of the study in the structural transformation literature has been focused on the role of consumption demand in the sectoral shift over time. Some of the recent work, like Song et al. (2011), Aghion et al. (2016), Buera and Shin (2017), Herrendorf et al. (2021), and García-Santana et al. (2021), among others, has emphasized the role of rising investment rate and its implication for growth. In any economy, the demand has two components - consumption demand and investment demand, and these two do not generally have the same composition. Due to standard income and price effects, sectors can reallocate within consumption and investment. Additionally, the reallocation also happens through shifts in expenditure between consumption and investment during transitional dynamics, driven by changes in the investment rate. The investment rate follows the hump shape with the growth of the per-capita income documented by García-Santana et al. (2021). A high investment rate leads to more allocation towards investment goods and, therefore, more capital for manufacturing and services growth.

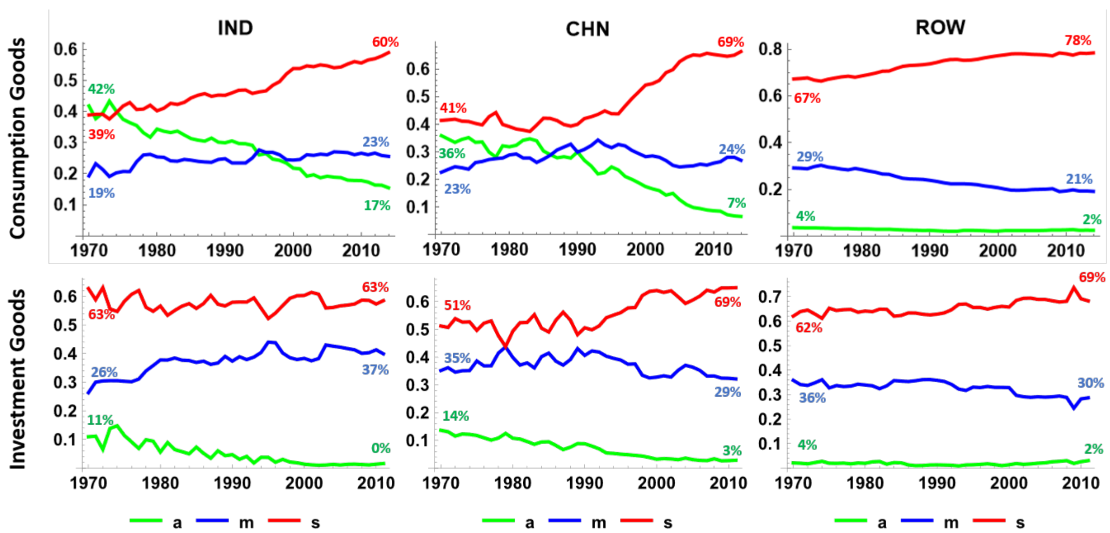

Figure 2: *Sectoral share of Consumption and Investment demand overtime (1970-2014: 1970 being year 0)*

In Figure 2, I present the sectoral shares of consumption and investment demand for three economies: India (IND), China (CHN), and an aggregate of the Rest of the World (ROW) (same aggregate is later used in the model), each at different stages of development. In all cases, investment demand tends to lead consumption demand, with the shares of manufacturing and services in investment rising well before they do in consumption. In India, by 1970, agriculture's share in investment value-added had already begun to decline, dropping to 11%, while its share in consumption remained significantly higher at 42%. Manufacturing, on the other hand, accounted for 26% of investment, surpassing its 19% share in consumption, reflecting a gradual shift from agriculture to manufacturing and eventually to services. This trend continued through 2014, with both investment and consumption shares in manufacturing still on the rise. In contrast, China's manufacturing investment and consumption shares peaked in the early 1990s at 44% and 37%, respectively, and have since been declining as services play an increasingly prominent role in the economy, a pattern that mirrors trends in the Rest of the World. It is important to emphasize again that the Indian share of manufacturing in investment is still growing, which might have implications for industrialization in the coming years.

In this paper, I write a multi-country, multi-sector general equilibrium model with non-homothetic consumption and investment demand, endogenous capital accumulation, asymmetric productivity growth, and international trade driven by comparative advantage to mimic the structural transformation in value-added, consumption, and investment expenditure in India and China. I quantify the model using macroeconomic sectoral data for the countries from 1970 to 2014. The period encapsulates the era of a closed economy in India and China and their globalization over time. Having developed a model that is able to match the data closely, I ran several counterfactuals to dissect the growth story of the two countries and the factors that differentiate them.

The carefully calibrated parameters and processes establish that China and India have differed significantly in their sectoral composition of value-added, consumption, and investment demand since 1970. China's economy was more manufacturing-driven, while India's has been more service-oriented even in 1970. However, the counterfactual reveals that China's rapid TFP growth, coupled with a high investment rate, has been the primary driver of its structural transformation, accounting for about 80% of its economic shift away from agriculture, with international trade contributing the remaining 20%. However, 73% of the Chinese manufacturing allocation is explained by trade. In contrast, India's transformation has been shaped more equally by TFP growth and trade, both of which played key roles in moving economic activities away from agriculture toward services. However, despite this shift, India's overall economic pie remains much smaller compared to China's. Also, in contrast to China, Indian services have a much more significant trade component, even though the sector is traditionally assumed to be non-tradeable.

To understand the prospects of industrialization in India, I ran a counterfactual by setting the Indian TFP growth rate to be the same as the Chinese in all three sectors. If that had happened, India's manufacturing share would have increased nearly 1.5 times, indicating that TFP growth is crucial for the sector. Also, export competitiveness further boosts the sector.

Related Literature

The paper speaks to several significant strands of the literature. Firstly, the paper contributes to the new literature on premature deindustrialization. It compares two major economies: one that witnessed the traditional structural transformation driven by the dominant role of industrialization and another whose growth story is non-conventional but more prevalent in today's developing countries, much like premature deindustrialization (Rodrik (2016)). Haraguchi et al. (2017) emphasizes that manufacturing shares in developing countries have stayed the same since 1970 due to the manufacturing activities being concentrated in only a few specific countries. Felipe et al. (2019), through their regression analysis, argues that becoming rich through industrialization has become much more difficult, largely because of rapid growth in the manufacturing capabilities of some very populous countries. Using a theoretical framework, Matsuyama and Fujiwara (2022) identifies the larger adoption lag in technology in the agriculture sector as one of the critical factors for premature deindustrialization. The most closely Sposi et al. (2021) confirms this phenomenon using a dynamic multi-country open economy model with two primary driving forces: sector-biased productivity growth and sectoral trade integration. This is still an evolving question, and more and more countries need to be studied to understand the phenomenon. This paper provides a very important comparative study to understand the phenomenon better.

The role of investment and a visible structural transformation in terms of sectoral investment demand is an important aspect that has not been emphasized enough in this literature. This paper relates to the evolving literature on the role of domestic and foreign investment in the growth of the manufacturing sector. Eaton et al. (2016), Mutreja et al. (2018), Ravikumar et al. (2019), Herrendorf et al. (2021), García-Santana et al. (2021) are some of the recent papers that have emphasized the role of investment in structural change. Most of the structural transformation models have been static models repeated every period, given exogenous shocks' processes. This paper contributes to the literature on dynamic, open economy structural change models along with Ravikumar et al. (2019), Sposi et al. (2021), García-Santana et al. (2021), among others. The paper also contributes to the literature by explicitly comparing the manufacturing-led transformation with the services-led structural change story. Sposi (2019) compares the pre-1990 and post-1990 industrialized nations and documents that sector-biased productivity growth is important for deindustrialization, whereas sectoral trade integration is important for industry polarization through increased specialization. This paper looks deeper into major economies, IND and CHN, and quantifies the importance of these channels in their transformation and draws some insights for industrialization through counterfactual analysis.

Lastly, the paper also contributes to the literature's understanding of the structural transformation in India. Dehejia and Panagariya (2010) studies the firm-level data from the NSSO survey to understand the regulations and frictions that contributed to India's unconventional growth story. Lamba and Subramanian (2020) studies the aspects of recent economic development in India from politics to gender, environment, and its implications on sustained structural change. Erumban et al. (2019) studies the India KLEMS data to comment on the role of productivity, human capital, and infrastructure development in structural change. [Mehrotra and Parida (2021)], [Erumban et al. (2019)], [Tejani (2016)], [Cortuk and Singh (2011)], [Kannan and Raveendran (2009)], [Bhalotra (1998)] among many others have studied the missing manufacturing in India and issues associated with it. However, my paper tries to understand the sectoral composition of the Indian economy through the lens of a detailed structural general equilibrium model quantified using structural macroeconomic data.

The remainder of the paper is structured as follows: Section 2 outlines the model used in the analysis. Section 3 describes the model quantification. I start with a short description of the data. A detailed description of the calibration of non-homothetic consumption parameters governing the income effects of the structural transformation is described, along with other time-variant demand parameters of the model. Then, I move to the supply side of the model and describe the estimation of the relative TFP growth, trade cost, and all other production parameters. The section concludes by discussing the fit of the baseline model with the data. Section 4 discusses the counterfactual results, decomposes the role of various channels in the structural transformation of IND and CHN, and provides a comparative study. Finally, Section 5 concludes the paper with the key findings.

2 Model

In this section, I describe the model used in the study. Similar to Uy et al. (2013), Świkecki (2017), Sposi (2019), I use a multi-country, multi-sector general equilibrium model with Ricardian trade. Following Eaton et al. (2016), Mutreja et al. (2018), Ravikumar et al. (2019) and Sposi et al. (2021), I also introduce endogenous capital accumulation. The agents have perfect foresight in these three countries and three sectors infinite horizon model. The representative households in each country make an intertemporal choice of consumption and investment and an intratemporal choice of consumption basket containing sectoral goods following non-homothetic preferences. A continuum of goods in each sector is produced by firms using labor, capital, and intermediates following constant returns to scale technology. These varieties are traded with standard iceberg trade costs. The heterogeneity among the countries is drawn from the labor endowment, the country and sector-specific productivities and trade costs, and their initial level of capital stock.

2.1 Households

Households in each country own a unit of time that is inelastically supplied in the labor market and an amount of capital that they rent out to produce goods. They make an intertemporal choice by choosing their consumption and investment over time. Also, they decide how much goods they want to consume from each sector every period.

2.1.1 Lifetime Utility

The lifetime utility is the sum of time-discounted period utilities, defined as follows:

$$U = \sum_{t=1}^{\infty} \beta^{t-1} \psi_{it} L_{it} \ln \left(\frac{C_{it}}{L_{it}} \right) \tag{1a}$$

where $\left(\frac{C_{it}}{L_{it}}\right)$ is the per capita aggregate consumption of country i at time t. β is the time discount factor, and ψ_{it} is the country- and time-specific exogenous shock to the discount factor. One can think of it as country-specific distortions that the model does not directly capture but might be affecting the investment decisions of the households. It is a wedge to capture any stochastic time-varying misalignment between the Euler equation and the data García-Santana et al. (2021).

2.1.2 Period Utility

Following Cravino and Sotelo (2019), Comin et al. (2021), Lewis et al. (2022), Sposi et al. (2021), and Matsuyama and Fujiwara (2022), I use the isoelastic non-homothetic CES preferences that explain the long-run households' behavior. In each period, the households have non-unitary substitution and sector-specific income elasticities of demand. The utility function is defined subject to the following consumption aggregator:

$$\sum_{\{k=a,m,s\}} (\omega_k^c)^{\frac{1}{\sigma}} \left(\frac{C_{it}}{L_{it}}\right)^{\frac{1-\sigma_c}{\sigma_c}\epsilon_k^c} \left(\frac{C_{ikt}}{L_{it}}\right)^{\frac{\sigma_c-1}{\sigma_c}} = 1 \tag{1b}$$

Where ω_k^c is the share-shift parameter for sector k's consumption, and σ_c is the price elasticity of substitution for consumption across sectors. ϵ_k^c is the sectoral income elasticity of substitution. C_{it} is the aggregate consumption whereas, C_{ikt} is the sector k's consumption of country i in period t. L_{it} is the total labor at time t. By solving the expenditure minimization problem, the sectoral consumption demand can be obtained as a function of the aggregate consumption price index (P_{it}^c) and the sectoral prices (P_{ikt}).

$$C_{ikt} = L_{it}\omega_k^c \left(\frac{C_{it}}{L_{it}}\right)^{(1-\sigma_c)\epsilon_k^c+\sigma_c} \left(\frac{P_{ikt}}{P_{it}^c}\right)^{-\sigma_c} \tag{1c}$$

where the aggregate price index for consumption goods is:

$$P_{it}^c = \left(\sum_k \omega_k^c \left(\frac{C_{it}}{L_{it}}\right)^{(1-\sigma_c)(\epsilon_k^c-1)} P_{ikt}^{1-\sigma_c}\right)^{\frac{1}{1-\sigma_c}} \tag{1d}$$

2.1.3 Aggregate Investment and Capital Accumulation

Each sectoral good is either consumed or saved and, in turn, invested. The share of income spent on investment goods contributes to capital formation. In the model, the goods invested from each sector (X_{ikt}) are aggregated using a similar Non-CES aggregator to get the country-level aggregate investment (X_{it}).

$$\sum_{\{k=a,m,s\}} (\omega_k^x)^{\frac{1}{\sigma}} \left(\frac{X_{it}}{L_{it}}\right)^{\frac{1-\sigma_x}{\sigma_x}\epsilon_k^x} \left(\frac{X_{ikt}}{L_{it}}\right)^{\frac{\sigma_x-1}{\sigma_x}} = 1 \tag{1e}$$

where ω_k^x is the share-shift parameter for sector k's investment, and σ_x is the price elasticity of substitution for investment across sectors, and ϵ_k^x is sectoral income elasticity. The sectoral investment demand (X_{ikt}) and the investment price index, therefore, can be represented as a function of the aggregate investment demand (X_{it}) and the sectoral prices(P_{ikt}).

$$X_{ikt} = L_{it}\omega_k^x \left(\frac{X_{it}}{L_{it}}\right)^{(1-\sigma_x)\epsilon_k^x+\sigma_x} \left(\frac{P_{ikt}}{P_{it}^x}\right)^{-\sigma_x} ;\& \quad P_{it}^x = \left(\sum_k \omega_k^x \left(\frac{X_{it}}{L_{it}}\right)^{(1-\sigma_x)(\epsilon_k^x-1)} P_{ikt}^{1-\sigma_x}\right)^{\frac{1}{1-\sigma_x}} \tag{1f}$$

The new investment and the undepreciated old capital stock contribute to capital formation, subject to the adjustment cost(λ). The new capital follows the Cobb-Douglas production function with λ share of new investment and $(1-\lambda)$ of the old undepreciated capital.

The law of motion for capital stock is as follows:

$$K_{it+1} = (1-\delta)K_{it} + X_{it}^{\lambda}\big(\delta K_{it}\big)^{1-\lambda} \tag{1g}$$

Where δ is the depreciation rate, and λ is a parameter to account for capital adjustment cost. $\lambda = 1$ means that there is no adjustment cost whereas $\lambda = 0$ means that there is infinite adjustment cost. The same equation can be rewritten to show investment as a function of the existing capital stock in this period and the desired capital stock next period as follows:

$$X_{it}(K_{it+1}, K_{it}) = \delta^{1-\frac{1}{\lambda}}\Big(\frac{K_{it+1}}{K_{it}} - (1-\delta)\Big)^{\frac{1}{\lambda}} K_{it} \tag{1h}$$

2.1.4 Period Budget Constraint

Every period, the households choose how much of each sector's goods to consume and how much to invest to maximize their lifetime utility given their period-wise budget constraint.

$$\sum_{k=\{a,m,s\}} P_{ikt}C_{ikt} + \sum_{k=\{a,m,s\}} P_{ikt}X_{ikt} = (1-\alpha_{it})\big(R_{it}K_{it} + W_{it}L_{it}\big) + L_{it}T_t^G \tag{1i}$$

Where the left-hand side of the budget constraint is the total expenditure on aggregate sectoral consumption and investment, on the right-hand side of the budget constraint, $R_{it}K_{it} + W_{it}L_{it}$ is the total income from factor supply. Following Caliendo et al. (2018) and Sposi et al. (2021), to account for the period-wise trade imbalances and to abstract from international borrowing and lending, it is assumed that a share α_{it} of income is invested in the global portfolio by the country i at time t. A lump-sum per capita T_t^G gets invested back from the global portfolio. So, the period t's trade imbalance is then $\alpha(R_{it}K_{it} + W_{it}L_{it}) - L_{it}T_t^G$.

2.1.5 Intertemporal households' Problem

Households are making their intertemporal consumption and investment choices to maximize their lifetime utility (1a), given the period-wise budget constraint (1i). The following Euler equation can summarize the intertemporal consumption-investment choice.

$$\frac{C_{it+1}/L_{it+1}}{C_{it}/L_{it}} = \beta\Big(\frac{\psi_{it+1}}{\psi_{it}}\Big)\left(\frac{(1-\alpha_{it+1})\frac{R_{it+1}}{P^x_{it+1}} - X_2(K_{it+2}, K_{it+1})}{X_1(K_{it+1}, K_{it})}\right)\left(\frac{P^x_{it+1}/P^c_{it+1}}{P^x_{it}/P^c_{it}}\right) \tag{1j}$$

where

$$X_1(K_{it+1}, K_{it}) = \frac{\delta^{1-\frac{1}{\lambda}}}{\lambda}\Big(\frac{K_{it+1}}{K_{it}} - (1-\delta)\Big)^{\frac{1-\lambda}{\lambda}}$$

$$X_2(K_{it+1}, K_{it}) = X_1(K_{it+1}, K_{it})\Big((\lambda - 1)\frac{K_{it+1}}{K_{it}} - \lambda(1-\delta)\Big)$$

The detailed derivation is provided in Appendix D. The equation represents that if a household gives up a unit of consumption (C_{it}/Lit) during this period, then that contributes to the capital formation and, therefore next period production, which in turn increases the consumption next period by an amount reflected by the right-hand-side of the equation.

2.2 Firms

There is a continuum of firms in each sector producing a variety using labor, capital, and some intermediates from each sector. These goods are traded across borders, so each firm competes with its counterparts in other countries. The firm that supplies at the cheapest price gets to sell it to the market, considering that goods are subject to standard iceberg trade costs when they cross borders. Given the total capital stock, labor, productivity, and trade cost, the firms face the same problem every period. So, the time subscript has been dropped in this subsection for simplification.

2.2.1 Technology

The production function for the variety of goods $z \in [0, 1]$ in sector $k \in \{a, m, s\}$ of country i is a Cobb-Douglas aggregator of labor, capital, and composite intermediate good M using the following technology.

$$Y_{ik}(z) = A_{ik}(z)\big((K_{ik}(z))^{\nu}(L_{ik}(z))^{(1-\nu)}\big)^{\phi_{ik}}\left(\prod_{n=\{a,m,s\}} M_{ikn}^{\gamma_{ikn}}(z)\right)^{1-\phi_{ik}} \tag{2a}$$

The sector-specific technology has a similar formulation for all countries; however, the parameters are different for each country. The parameter ϕ_{ik} is the share of value-added in the output, whereas ν is the share of capital in the value-added. The intermediate aggregate is sourced from n sectors in the proportion of γ_{ikn} for production in sector k. An inelastic, perfectly mobile labor and capital facilitate equal wages and rental rates across sectors in a country. The country-specific factor share is heterogeneous among sectors but is the same for all varieties in a specific sector, enabling identical unit variable cost ($\equiv V_{ik}$). Hence, the firms' optimization problem can be solved in the sectoral aggregate form. A_{ik} is the sectoral aggregate productivity. A detailed discussion on this is in the following subsection. As markets are perfectly competitive, prices are equal to the marginal cost of production. The marginal conditions for the inputs and the sectoral unit variable cost are derived from the first-order conditions.

$$R_i K_{ik} = \nu\phi_{ik} P_{ik} Y_{ik}; \quad W_i L_{ik} = (1-\nu)\phi_{ik} P_{ik} Y_{ik}; \quad P_{in} M_{ikn} = \gamma_{ikn}(1-\phi_{ik}) P_{ik} Y_{ik}$$

$$P_{ik} = \frac{1}{A_{ik}} \left(\frac{R_i}{\nu\phi_{ik}}\right)^{\nu\phi_{ik}} \left(\frac{W_i}{(1-\nu)\phi_{ik}}\right)^{(1-\nu)\phi_{ik}} \left(\frac{\prod_{n=a,m,s}\left(\frac{P_{in}}{\gamma_{ikn}}\right)^{\gamma_{ikn}}}{1-\phi_{ik}}\right)^{1-\phi_{ik}} \equiv \frac{V_{ik}}{A_{ik}} \tag{2b}$$

2.2.2 Productivity and Prices

Following the seminal paper Eaton and Kortum (2002), the $A_{ik}(z)$ (2a) is an exogenous time, country, and sector-specific productivity drawn from a Fréchet distribution. It is a realization of z_{ik} drawn from a cumulative distribution $F_{ik}(z) = Exp[-(T_{ik}^{-\phi_{ik}} z)^{-\theta}]$ where T_{ik} is the country and sector-specific scale parameter of the Frechet distribution, whereas θ is the shape parameter representing the heterogeneity in the productivity across varieties.

When a variety travels beyond the country's border, the price is increased by the standard iceberg trade cost defined as only a fraction $(1/d_{ijk})$ of the good produced in the country j is utilized in the country i. Hence, the price of a variety z in a sector $k \in \{a, m, s\}$ in country i is $P_{ijk}(z) = d_{ijk}\Big(V_{ijk}/A_{ijk}(z)\Big)$ following (eqn 2b). Each country has the technology to produce all varieties, but the buyers will choose to buy from the country with the lowest prices. Therefore, the market price of a variety in a country is defined as $P_{ik}(z) \equiv min_j\{P_{ijk}(z)\}$. The total composite supply of all varieties in a sector, Q_{ik}, is a CES aggregator with an elasticity of substitution across varieties denoted by η.

$$Q_{ik} = \left(\int_0^1 Q_{ik}(z)^{\frac{\eta-1}{\eta}})dz\right)^{\frac{\eta}{\eta-1}} \tag{2c}$$

By the law of large numbers and the Ricardian selection of varieties across the border, the prices become the joint probability of a variety having superior productivity. Hence, the price of the sectoral composite in sector k in country i is

$$P_{ik} = \xi(\Phi_{ik})^{-1/\theta} \tag{2d}$$

where ξ is the Euler gamma function evaluated at $(1-(\eta-1)/\theta)$ and raised to the power $1/(1-\eta)$. For any sectors, $k = \{a, m, s\}$, $\Phi_{ik} = \sum_{j=1,2,3}(T_{jk}^{-\phi_{jk}} V_{jk} d_{ijk})^{-\theta}$. These aggregate prices map to the prices in equation (2b).

Given the sectoral prices, the trade share (π_{jik}) of country i in the expenditure of country j is the ratio of the effective productivity of country i over the total effective productivity of the world.

$$\pi_{jik} = \frac{(T_{ik}^{-\phi_{ik}} V_{ik} d_{jik})^{-\theta}}{\Phi_{jk}} = \frac{(T_{ik}^{-\phi_{ik}} V_{ik} d_{jik})^{-\theta}}{\sum_{j=1,2,3} (T_{jk}^{-\phi_{jk}} V_{jk} d_{ijk})^{-\theta}} \tag{2e}$$

Under Ricardian selection, the sectoral aggregate productivity A_{ik} in equation (2b) is the aggregate productivity of all the domestic varieties that have superior productivity, also termed as measured productivity. The productivity under autarky, however, represents the fundamental productivity of the country.

$$T_{ik} = (\xi A_{ik} \pi_{iik}^{\frac{1}{\theta}})^{\frac{1}{\phi_{ik}}} \tag{2f}$$

The share of domestic absorption $\pi_{iik} < 1$. In the closed economy $\pi_{iik} = 1$. Therefore, $A_{ik,o}/A_{ik,c} = \pi_{iik}^{-1/\theta} > 1$, reflecting that the aggregate productivity is higher when there is trade, as shown by Finicelli et al. (2013).

All the firm's optimization problem variables are obtained at the sectoral aggregate level. The prices for each sector for all countries are determined as a function of labor endowments, productivity, trade costs, and exogenous parameters of the model. The entire production side problem is now reduced to the form of sectoral aggregates.

2.3 Market Clearing Conditions

First, the value of total goods produced in a sector by a country is equal to the sum of the domestic and foreign use of that good. The following equation can present this condition.

$$P_{ikt} Y_{ikt} = \sum_{j=1,2,3} \left(\pi_{jikt} P_{jkt} Q_{jkt} \right) \tag{3a}$$

The capital market clears when the total capital used in producing goods equals the total amount of capital available in the economy every period. Using the first-order condition concerning the capital of the firm's problem and summing it over all sectors gives us the capital market clearing condition.

$$R_{it} K_{it} = \sum_{k=a,m,s} \left(\nu \phi_{ik} P_{ikt} Y_{ikt} \right) \tag{3b}$$

Similar to the capital market, given the uniform sectoral wages, the labor income of the country is the sum of the labor share of the VA of all the sectors. The same is summarized as the country-specific labor market clearing conditions.

$$W_{it}L_{it} = \sum_{k=a,m,s} \Big((1-\nu)P_{ikt}Y_{ikt}\Big) \tag{3c}$$

Every period, all goods market clear. The sectoral composite good Q_{ikt} is used for domestic demand of final consumption and investments and intermediate inputs demand for the home and foreign production.

$$Q_{ikt} = C_{ikt} + X_{ikt} + \sum_{n=a,m,s} \left(\frac{\gamma_{ink}(1-\phi_{in})P_{ikt}Y_{ikt}}{P_{int}}\right) \tag{3d}$$

Therefore, a country's net exports are the difference between its total production and total use, which is also equal to the share of GDP sent to the global portfolio net of transfers received from abroad (T_t^G).

$$NX_{it} = \sum_{k=a,m,s} \big(P_{ikt}Y_{ikt} - P_{jkt}Q_{jkt}\big) = \alpha_{it}(R_{it}K_{it} + W_{it}L_{it}) - L_{it}T_t^G \tag{3e}$$

The global trade should balance every period ($\sum_{i=1,2,3} NX_{it} = 0$). This, in turn, means that the sum of each country's investment in the global portfolio will equal the sum of the total transfers to all countries.

$$\sum_{i=1,2,3} \alpha_{it}(R_{it}K_{it} + W_{it}L_{it}) = \sum_{i=1,2,3} L_{it}T_t^G \tag{3f}$$

2.4 Competitive Equilibrium

In this model economy, the following are exogenously determined.

- Exogenous time-invariant common structural parameters: time discount factor β, price-elasticity of demand for consumption goods σ_c and investment goods σ_x, income elasticity of demand $\{\epsilon_k^c, \epsilon_k^x\}_{k=a,m,s}$, sectoral share parameter of consumption and investment goods $\{\omega_k^c, \omega_k^x\}_{k=a,m,s}$, elasticity of substitution between varieties in a sector η, trade elasticity parameter θ, rate of depreciation of capital δ and parameter for adjustment cost of capital λ, share of capital in the value-added ν, parameters for value-added and sectoral share of intermediates in production $\{\phi_{ik}, \gamma_{ikn}\}_{n,k=a,m,s}$, and country-specific initial capital stock K_{i0}.

- Exogenous time-variant country-specific labor endowment processes $\{L_{it}\}$, trade cost processes $\{d_{ijkt}\}_{k=\{a,m,s\}}$, productivity processes $\{T_{ikt}\}_{k=\{a,m,s\}}$, the idiosyncratic preference shock ψ_{it}, share of global investment α_{it} and lump-sum per capital global transfers T_t^G.

Given these exogenous parameters and processes, a competitive equilibrium is a sequence of endogenously determined processes sectoral & aggregate goods prices $\{P_{iat}, P_{imt}, P_{ist}, P_{it}^c, P_{it}^x\}$ and factor prices $\{R_{it}, W_{it}\}$, goods allocations $\{Q_{iat}, Q_{imt}, Q_{ist}\}$, $\{C_{iat}, C_{imt}, C_{ist}\}$, $\{X_{iat}, X_{imt}, X_{ist}\}$, factor allocation $\{K_{iat}, K_{imt}, K_{ist}\}$, $\{L_{iat}, L_{imt}, L_{ist}\}$, and trade shares $\{\pi_{ijkt}\}_{k=\{a,m,s\}}$ such that firms maximize profit, households maximize their utilities, and all capital, labor, and goods markets are clear in all countries.

3 Model Quantification

3.1 Data

In this section, I broadly describe the data. The countries are IND, CHN, and the aggregate of the rest of the world (ROW). ROW is an aggregate of 54 countries from across the globe. Twenty rich countries, including the United States, Australia, and many from Europe, 11 Asian Countries, 7 Latin American countries, and 18 African countries. A detailed list of countries is provided in the data appendix A. The time frame of 1970-2014 is chosen to capture the effect of pre- and post-changes of globalization policy in IND and CHN.

The sectors are defined per the International Standard Industrial Classification of all Economic Activities, Revision 4 code definitions. Agriculture includes agriculture, hunting, forestry, fishing (A), mining, and quarrying (B). Manufacturing is an aggregate of manufacturing (C) and Electricity, Gas, and Water Supply (DtE). Service is an aggregate of all other sectors from F to U.

I rely on multiple data sources to build a comprehensive dataset for the analysis. The primary data sources are the GGDC Economic Transformation Database, EU KLEMS data (2007 and 2009 releases), the World Input-Output Database (WIOD) (LR-WIOT, 2013 and 2016 releases), and the Penn World Table 8.1. The WIOT database includes data on gross output, value-added, spending on intermediates, final consumption & investments, and bilateral trade. The nominal data is used to obtain all shares: value-added share, sectoral intermediates' use share, sectoral bilateral trade shares, and relative consumption and investment spending. I collapse the sub-sectors into three sectors consistent with the definition mentioned above. For data on employment and Value added at current and constant prices, I mainly rely on the GGDC Economic Transformation Database Historic series and the EU KLEMS database. The data on PPP conversion factors have been obtained from the OECD and the World Bank Database. The initial level of capital stock is obtained from the Penn World Table. A detailed description of the data is provided in Appendix A.

3.2 Calibration of Time-invariant Parameters

3.2.1 Consumption Demand Parameters

To calibrate the parameters $(\omega_a^c, \omega_m^c, \omega_s^c, \sigma^c, \epsilon_a^c, \epsilon_m^c, \epsilon_s^c)$, I use the model itself. The household's problem provides the country and sector-specific consumption expenditure. The parameters are calibrated by minimizing the squared distance between the observed sectoral expenditure (data) and the model-calculated sectoral expenditure given observed sectoral prices. I also impose three constraints. First, the sum of ω_a^c, ω_m^c, and ω_s^c is normalized to 1. This is done because only two ω^c can be estimated given the specification, but such normalization allows for calculating all three relative share-shift parameters without the loss of generality. Second, the income elasticity of the manufacturing sector is normalized to 1. The sectoral income elasticities are interpreted relative to the manufacturing sector. This normalization does not affect the equilibrium results because only the difference in the income elasticities matters for allocation. The different values of ϵ_m, while holding the difference constant, are the monotonic transformation of the same utility function. Third, the aggregate consumption (C_{it}) is implicitly obtained from the model using observed sectoral expenditure and sectoral prices (eqn 1d). Formally, I want to solve the following problem. All the observed variables are written with a hat.

$$\mathbf{Min}_{\sigma,\epsilon_k^c} \sum_t \sum_i \sum_k \left(\frac{\hat{E}_{ikt}}{\hat{E}_{imt}} - \left(\frac{\omega_k^c}{\omega_m^c}\right)\left(\frac{P_{ikt}}{P_{imt}}\right)^{1-\sigma_c}\left(\frac{C_{it}}{\hat{L}_{it}}\right)^{(1-\sigma_c)(\epsilon_k^c-1)} \right)^2$$

$$\text{Subject to;} \quad \sum_k \omega_k = 1; \quad \epsilon_m = 1; \quad \text{and } \frac{\sum_k \hat{E}_{ikt}}{\hat{L}_{it}} = \left(\sum_k \omega_k^c P_{ikt}^{1-\sigma_c} \left(\frac{C_{it}}{\hat{L}_{it}}\right)^{(1-\sigma_c)\epsilon_k^c} \right)^{\frac{1}{1-\sigma_c}}$$

To run the above-said regression, I need time series data on sectoral expenditure, aggregate consumption, and the sectoral gross output prices.

Sectoral Consumption Expenditure: The sectoral expenditure data is observed in the WIOD, where consumption is an aggregate of household and government consumption. I aggregate the data across sectors and countries in 3 sectors and 3 countries, suited for my model. The data in the WIOD is presented in nominal USD terms; I convert them to current PPP USD.

Sectoral Prices: First, I collate data on nominal and real value added from the EU KLEMS and GGDC Economic Transformation Database for sectoral prices. EU KLEMS and GGDC provide data in national currencies, so I convert them into PPP USD using the PPP conversion factor for GDP from the OECD and the World Bank database. I use the Tornqvist Method to aggregate the real value-added into the three sectors and then convert them at 2005 prices. The ratio of nominal and real value added gives the sectoral value-added prices relative to 2005 prices. All sectoral prices for all countries are 1 for 2005, so it is not comparable across sectors and countries. GGDC Productivity Level Database 2005 benchmark provides Sectoral PPP VA prices for 2005 for 42 countries and three major sectors relative to the USA GDP price. I aggregate the countries other than IND and CHN as ROW using their share of PPP value-added in the total ROW's value-added. Thus, found 3-sector 3-country 2005 internationally comparable VA prices are now used to splice the model-calculated VA prices to have comparable prices. However, I need the sectoral gross output prices, so I use the model to gross up value-added prices to gross output prices. The derivation is provided in Appendix D.

$$(\widehat{VAprc})_{ikt} = \phi_{ik} P_{ikt}^{\frac{1}{\phi_{ik}}} \left((1-\phi_{ik}) \prod_{n=\{a,m,s\}} \left(\frac{\gamma_{ikn}}{P_{int}} \right)^{\gamma_{ikn}} \right)^{\frac{1-\phi_{ik}}{\phi_{ik}}} \tag{4a}$$

Thus, sectoral prices are obtained by solving the nine simultaneous equations (4a)), which are then used in the estimation process.

Aggregate Real Consumption: Since the model's consistent aggregate real consumption C_{it} is not observed, the aggregate consumption price index equation is used to compute it. The per-capita consumption expenditure and sectoral prices are required to estimate the level of aggregate consumption, but to do so, I need all the share-shift parameters and elasticities. However, by using the one-period deviation (the gross growth rate) of all the variables defined as $\dot{X}_t \equiv \frac{X_t}{X_{t-1}}$, I can estimate the growth rate of aggregate consumption with just the three elasticity parameters. The growth rate equations are derived using the aggregate consumption price index equation (1c). Detailed derivation is provided in Appendix

D.

$$\frac{\hat{\dot{E}}_{it}}{\hat{\dot{L}}_{it}} = \left(\sum_k \hat{e}_{ikt-1} \dot{P}_{ikt}^{1-\sigma_c} \left(\frac{\dot{C}_{it}}{\hat{\dot{L}}_{it}} \right)^{(1-\sigma_c)\epsilon_k^c} \right)^{\frac{1}{1-\sigma_c}} \tag{4b}$$

All variables other than $\dot{C}_{it}$ in equation (4b) are coming from the data. So, if elasticities are known, then the growth rate of aggregate consumption is obtained by solving three simultaneous sectoral expenditure share equations (4b).

Elasticities' Estimation: In the model, I have the sectoral expenditure as a function of sectoral prices, aggregate consumption, and the parameters using equation (1c). Assuming that manufacturing has unit income elasticity, the income elasticity of the other two sectors is calibrated relative to manufacturing. Since I have the growth rate of aggregate consumption, I also derive the equation for the ratio of the growth rate of consumption expenditure, which is then used for estimating the elasticity parameters. In log terms, the equation is written as (4c).

$$\ln\left(\frac{\hat{\dot{E}}_{ikt}}{\hat{\dot{E}}_{imt}}\right) = (1-\sigma_c)\ln\left(\frac{\dot{P}_{ikt}}{\dot{P}_{imt}}\right) + (1-\sigma_c)(\epsilon_k^c - \epsilon_m)\ln\left(\frac{\dot{C}_{it}}{\hat{\dot{L}}_{it}}\right) \tag{4c}$$

Algorithm: Since the estimation of the real aggregate consumption and elasticity parameters is dependent on each other, so to do this, I use the iterative estimation process similar to Deaton and Muellbauer (1980) Lewis et al. (2022) and Sposi et al. (2021). I first guess the parameters and then compute $\dot{C}_{it}$ as a solution of the system of equations (4b). With thus obtained $\dot{C}_{it}$, I run the constrained regression mentioned in equation (4c) with country fixed effects and sector dummy and its interaction with a growth rate of the real consumption to estimate the parameters. Thus, estimated parameters are used to construct the new measure of $\dot{C}_{it}$ and re-run the regression till the parameters converge. I use data for all three countries: IND, CHN, and ROW. The HP filter is used to exclude short-term deviations. The parameters obtained are reported in Table 1.

Table 1: *Consumption Demand Elasticity Parameters*

σ_c	ϵ_a^c	ϵ_m^c	ϵ_s^c
0.183	0.397	1	1.184

Elasticity Parameters' values: I obtain the price elasticity of the demand $\sigma^c = 0.183$, the income elasticity of the agriculture demand $\epsilon_a = 0.397$, and that of the services demand $\epsilon_s = 1.184$. The estimated growth rate of the real aggregate consumption and the fit to the growth rate of the model calculated expenditure ratios are presented in Figure 12. $0 < \sigma^c < 1$ implies that sectoral goods are complements. ($\epsilon_a < 1$) is consistent with the fact that agriculture is a necessity, whereas $\epsilon_s > 1$ categorizes services as luxury goods. My estimates are comparable to the ones found in the literature in a similar setup. Sposi et al. (2021) finds σ equals 0.23, whereas their estimates of ϵ_a and ϵ_s are 0.102 and 1.333, normalizing ϵ_m to 1 for a sample of 30 countries (not necessarily matching with my sample). Comin et al. (2021) finds a point estimate for $\sigma \in (0.25 - 0.63)$, $\epsilon_a \in (0.01, 0.20)$, and $\epsilon_s \in (1.17, 1.37)$. Lewis et al. (2022) finds $\sigma = 0.16$ and $\epsilon_s = 1.73$ in a two-sector model. Uy et al. (2013) finds $\sigma = 0.75$ with Stone-Geary non-homothetic preferences. The parameters capture the long-term trends of the data.

Sectoral Share-shift Parameters to the Consumption Demand: Without the loss of generality, the sum of sectoral share-shift parameters has been normalized to 1. I estimate them to match the consumption expenditure share, the sectoral prices, and the total consumption expenditure in the first year (1970). Solving for the parameters from the expenditure share equation and then summing them over all sectors and substituting for $C_{it} = \hat{E}_{it}/P^c_{it}$, the resulting equation has just one unknown variable P^c_{it}.

$$1 = \sum_{k=a,m,s} \omega^c_k = \sum_{k=a,m,s} \left(\frac{\hat{E}_{ik,1970}}{\hat{E}_{i,1970}}\right) \left(\frac{P_{ik,1970}}{(P^c_{i,1970})^{\epsilon^c_k}} \left(\frac{\hat{E}_{i,1970}}{\hat{L}_{i,1970}}\right)^{\epsilon^c_k - 1}\right)^{\sigma_c - 1} \tag{4d}$$

After calculating the price index from equation (4d) and the consumption index (E_{it}/P_{it}), the weights are calculated by substituting them in the sectoral share-shift parameters equation.

$$\omega^c_{ik} = \left(\frac{\hat{E}_{ik,1970}}{\hat{E}_{i,1970}}\right) \left(\frac{P_{ik,1970}}{P^c_{i,1970}} \left(\frac{C_{i,1970}}{\hat{L}_{i,1970}}\right)^{\epsilon^c_k - 1}\right)^{\sigma_c - 1} \tag{4e}$$

I calculate the parameters for each country separately and then average them across countries.

3.2.2 Investment Demand Parameters

Using the same methodology and the same data source for sectoral investment expenditure, I calibrate the investment demand elasticities and the share-shift parameters.

The price elasticity $\sigma_x = 0.49 > 1$ shows that sectoral investments are complements. The parameter estimates vary a lot in the literature. My estimates are near to the ones found in literature in similar settings. Using a sample of 28 developed and developing countries,

Table 2: *Investment Demand Elasticity Parameters*

σ_x	ϵ_a^x	ϵ_m^x	ϵ_s^x
0.494	0.209	1	1.198

Sposi et al. (2021) finds it to be 0.38 when sectoral investment demand is restricted to have only the price effect. García-Santana et al. (2021) finds 0.51 in a similar CES aggregation where the sectoral shares within investment only depend on relative prices. The parameter is 0 in a two-sector model used by Herrendorf et al. (2021) using US post-war data. My income elasticity estimates are comparable to $\epsilon_a^x = 0.3$ and $\epsilon_s^x = 1.08$ found by Sposi et al. (2021). Similar to the consumption demand, the investment demand's share shift parameters are calculated to match the first year's sectoral investment expenditure shares.

3.2.3 Production Parameters

The VA parameters $\{\phi_{ik}\}_{k=\{a,m,s\}}$ are obtained by calculating the share of VA in the gross output for each sector in each country using the World Input-output Database, presented in Table 3. Generally, value-added shares are highest in services and lowest in manufacturing, but IND and CHN both have the highest ratio in agriculture. Also, two things are essential to note here. First, IND's manufacturing value-added share is much lower compared to CHN and ROW, which can be interpreted as the manufacturing sector reassembling/repackaging the intermediates to a larger extent than producing goods. Secondly, Chinese services have substantially lower value-added.

Table 3: *Production Parameters of the model (VA share)*

ϕ_{ik}	Agriculture	Manufacturing	Services
IND	0.7594	0.2462	0.6370
CHN	0.5959	0.2681	0.4595
ROW	0.5852	0.3353	0.6021

I calculate the time-invariant country-specific, technology parameters, $\{\gamma_{ikn}\}_{k,n=\{a,m,s\}}$ using the data from WIOT. I reduce the commodity-industry absorption table for every year into three sectors. The share of all the sectors' commodities absorption in the three aggregated industries gives a 3x3 matrix for intermediate share-shift parameters. The parameters are reported in Table 4. The parameter values are the element-wise sample mean of all yearly matrices.

Table 4: *Production Parameters of the model (Intermediate shares)*

	γ_{ikn}	Agriculture	Manufacturing	Services
IND	Agriculture	0.5070	0.2398	0.2532
	Manufacturing	0.2173	0.5115	0.2713
	Services	0.0689	0.4749	0.4562
CHN	Agriculture	0.3478	0.4792	0.1730
	Manufacturing	0.1843	0.6676	0.1481
	Services	0.0560	0.5694	0.3746
ROW	Agriculture	0.3223	0.3528	0.3249
	Manufacturing	0.1591	0.5621	0.2788
	Services	0.0179	0.2998	0.6824

The table shows that IND's share of intermediates is relatively higher from the primary agriculture sector than that of the modern manufacturing and services sector in the production process in all three sectors compared to that of CHN and ROW. Sposi (2019) also finds similar results.

3.2.4 Other Parameters taken from Literature

The share of capital in the value-added (ν) is set equal to 0.4 (the average share of all the countries over time). It is worth pointing out here that in the data, CHN and ROW have a relatively stable capital share of about 40-42% over time, whereas IND's share has changed significantly from 25%(1970) to 48%(2014). The time discount factor (β) is set equal to 0.96 to target a 4% intertemporal return reflected by the interest rate. The trade elasticity (θ) is set equal to 4 following Waugh (2010). Following the literature, the elasticity of substitution between varieties (η) is set equal to 2, assuming that varieties in a sector are gross substitutes. As shown in Eaton and Kortum (2002), the elasticity of substitution between varieties in a sector does not play any role in these models. The depreciation rate (δ) is equal to 6%, and the adjustment cost elasticity (λ) is set to be 0.85, which is consistent with the one used in Eaton et al. (2016). A larger λ means a lower capital adjustment cost.

Table 5: *Other Common Parameters*

Capital share in the value-added	ν	0.40
Trade elasticity	θ	4
Elasticity of substitution between varieties	η	2
Time Discount factor	β	0.96
Depreciation rate for capital	δ	0.06
Capital Adjustment cost elasticity	λ	0.85

3.3 Calibration of Time-varying Exogenous Processes

3.3.1 Labor Endowments

I rely on GGDC ETD and the EU KLEMS database for labor endowment and sectoral EMP share data. The EMP for the ROW is built by simple addition across 52 countries in the sample for the three sectors.

3.3.2 Productivity Parameters

Since the detailed sectoral intermediates data series derived from the input-output table is only available for some countries, TFP can not be estimated directly from the production technology. I calibrate the productivity parameters in two steps.

1. First, I calibrate the nine(9) fundamental TFP parameters (T_{ik}) for each sector and country such that sectoral VA shares and the relative factor prices match with the data. The targeted and model moments are reported in Table 6.

Table 6: *Targets for Calibrating TFP in 1970 (First Year)*

Variables	Target	Model
IND Agricultural VA share	43.35%	42.35%
IND Manufacturing VA share	15.68%	16.06%
CHN Agricultural VA share	39.60%	39.03%
CHN Manufacturing VA share	32.92%	31.92%
ROW Agricultural VA share	9.19%	8.70%
ROW Manufacturing VA share	32.41%	33.4%
CHN-IND wage ratio	0.30	0.45
ROW-IND wage ratio	5.85	10.85
CHN-IND capital rental rate ratio	2.38	3.54

2. In the second step, I estimate measured productivity parameters (A_{ikt}) using equation 2b reproduced below, which uses the first-order marginal conditions of the firm's problem. To do so, I need factor prices - the rental rate of capital (R_{it}), the wage rate (W_{it}), and the sectoral gross-output prices, along with the time-invariant parameters. The gross-output prices are estimated in section 3.2.1.

$$A_{ikt} = \frac{1}{P_{ikt}}\left(\frac{R_{it}}{\nu\phi_{ik}}\right)^{\nu\phi_{ik}}\left(\frac{W_{it}}{(1-\nu)\phi_{ik}}\right)^{(1-\nu)\phi_{ik}}\left(\frac{\prod_{n=a,m,s}\left(\frac{P_{int}}{\gamma_{ikn}}\right)^{\gamma_{ikn}}}{1-\phi_{ik}}\right)^{1-\phi_{ik}}$$

Factor Prices: From the first-order condition, the rental rate of capital and the wage rate are estimated using data for nominal GDP at PPP USD, and the labor endowment and estimated capital stock (as described below).

$$R_{it} = \frac{\nu(\widehat{VA})_{it}}{K_{it}}; \quad W_{it} = \frac{(1-\nu)(\widehat{VA})_{it}}{L_{it}}$$

Capital Stock: The series of Capital Stock is estimated using the law of motion of the capital stock from equation 1g, total investment expenditure, and the investment price index from equation 1f. Using the total investment expenditure and the investment price index, I calculate the aggregate investment series using $X_{it} = \frac{\left(\sum_{k=a,m,s} \widehat{P_{ikt}X_{ikt}}\right)}{P^x_{it}}$. Thus, the obtained investment series, along with the initial level of capital stock ($K_{i,1970}$) from the Penn World Table, is imputed in the law of motion of the capital stock to get the entire series.

3. Following the relationship shown by Finicelli et al. (2013), I calculate the fundamental productivity parameters (T_{ikt}), given measured productivity (A_{ik}) from step 2 and the share of the domestic absorption (π_{iik}). The derivation is provided in Appendix D.

$$T_{ikt} = \left(\xi A_{ikt}\pi_{iikt}^{\frac{1}{\theta}}\right)^{\frac{1}{\phi_{ik}}}$$

I then calculate the growth rate of the fundamental productivity and apply that to the first year's productivity calibrated in step 1.

The time series of the logged fundamental TFP series is summarized in Figure 3. It provides a cross-country intra-sector comparison. TFP is highest in all three sectors in the rest of the world and lowest in IND. From 1970 to 2014, the fundamental TFP in agriculture

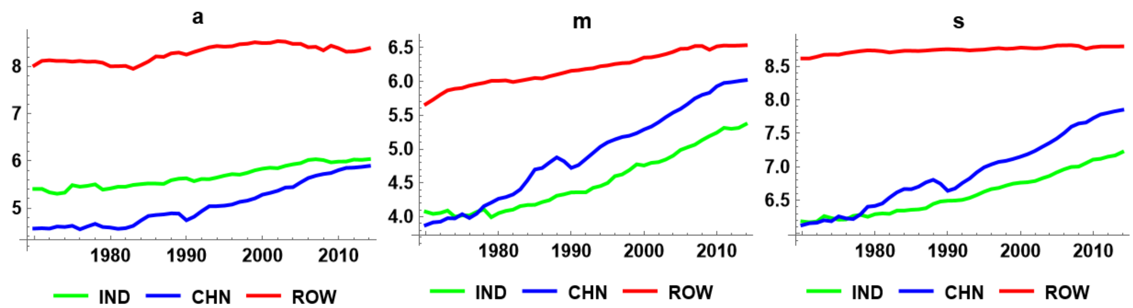

Figure 3: *The estimated productivity processes for all three countries*

grew by 44% in ROW, 276% in CHN, and merely 88% in IND. During the same period, Indian TFP grew by 265% in manufacturing and 182% in Services, whereas Chinese TFP grew by 754% and 460%, respectively. The annualized TFP growth rates were 1.41% in agriculture, 2.92% in manufacturing, and 2.33% in services in IND during this period. In CHN, they were 2.99% in agriculture, 4.88% in manufacturing, and 3.90% in services. In ROW, TFP grew at the rate of 0.81% in agriculture, 1.95% in manufacturing, and 0.40% in services. The manufacturing sector experiences more rapid TFP growth than the other two sectors in all three countries. The Chinese TFP grew much faster compared to others, particularly in agriculture and manufacturing, which facilitated first the shift out of agriculture and then increased the share of manufacturing.

3.3.3 Iceberg Trade Costs

The WIOD database provides information on bilateral trade between each country and sector. I collapse the subsectors into three sectors. The bilateral trade share for each pair in each sector is defined as follows:

$$\pi_{ijkt} = \frac{X_{ijkt}}{ABS_{ikt}}$$

where X_{ijkt} is the trade flow from country j to i in sector k.

ABS_{ikt} is the domestic absorption of the country i in sector k, obtained by subtracting the net exports from the Gross Output at the current prices. The Sectoral Gross Output data is also obtained from the same source (WIOD). The model is then used to calibrate the bilateral iceberg trade cost so that the model-calculated trade share matches the data.

$$d_{ijkt} = \mathbf{Max}\left[\left(\frac{\pi_{ijkt}}{\pi_{jjkt}}\right)\left(\frac{p_{ikt}}{p_{jkt}}\right), 1\right] \tag{4f}$$

In the last three decades, IND and CHN have seen a surge in imports from the rest of the world in all three sectors. Also, Chinese manufacturing exports to IND and ROW have risen since the early 2000s. However, IND has no visible export share with other trading partners. These interactions are essential factors for sectoral growth and structural change. The model predicts the bilateral shares almost accurately for all pairs. However, it underestimates CHN's manufacturing exports to the rest of the world by about 2 percentage points.

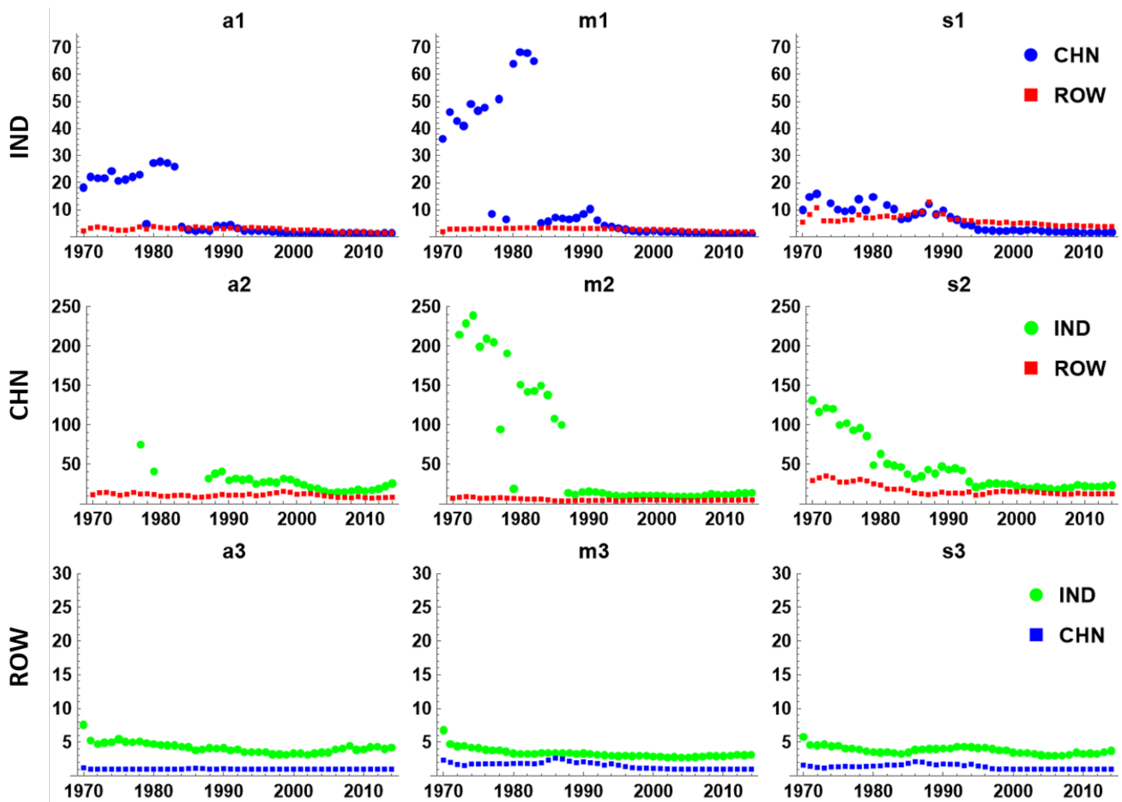

Figure 4: *The sectoral iceberg import cost of each bilateral trade partner.*

Attune with the trade relations, the iceberg trade cost (shown in figure 4) has declined between all trading partners over time in the model. A sharp decline in IND's import cost can be seen during the early 1990s. Import costs in CHN also started declining in the mid-1980s. However, it is crucial to observe that the ROW's import from CHN is cheaper than that of IND in all three sectors, which also signifies that CHN has had access to a more extensive market for its products.

3.3.4 Share of global investment

The share of global investment is calculated as the share of net exports in total value-added. The data on net exports and value-added is obtained from the WIOD.

$$\alpha_{it} = \frac{NX_{it}}{VA_{it}} \tag{4g}$$

Beginning 1990s and prominently after the China Shock, CHN has been running a huge trade surplus with almost all its trading partners. On the other hand, the opening up of the economy and its energy dependence on imports have led to a consistent trade deficit for IND over the last three decades.

3.3.5 Preference Shock Parameters

I obtain the per-capita consumption expenditure growth rate and consumption price index from section 3.2.1. The investment price index, aggregate investment, and capital stock are estimated in section 3.3.2. Given these, I use the Euler equation (Equation 1j) to estimate the preference shock parameters ψ_{it+1} assuming $\psi_{i,1970} = 1$.

3.4 Model fit with the data

I use the model to calculate the sectoral value-added share in all three sectors for IND and CHN. The model computed shares and its fit with the data are shown in Figure 5. I want to point out here that only the VA share in 1970 is targeted; the entire series after that evolves based on the mechanism in the model.

The model does a decent job of predicting the VA shares for all sectors in IND and CHN. However, it predicts a relatively slower structural change in CHN than the actual. The Mean Absolute Error of the estimation is reported in the table 7. Also, given the initial level of capital and the calibrated preference shock to the discount factor, the capital accumulates endogenously. The model matches well the nominal investment rate and the level of capital stock with the data for both IND and CHN.

Table 7: *Mean Absolute Error of Estimation*

	Agriculture	Manufacturing	Services
IND	3.02%	2.52%	1.15%
CHN	3.35%	2.42%	4.93%

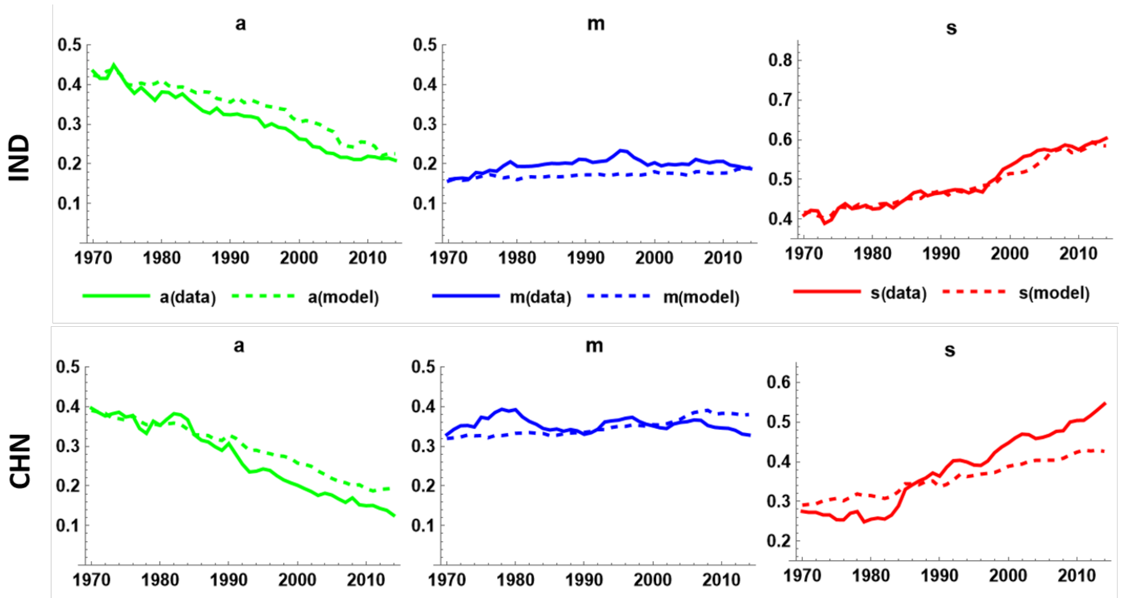

Figure 5: *The sectoral share of value added in a(agriculture), m(Manufacturing), and s(services) predicted by the model and its comparison with the data.*

The model also does a good job of matching the investment share of the value-added and the sectoral consumption and investment expenditure shares. For Sectoral consumption expenditure shares, it matches the trends but misses the levels. It overestimates the agricultural share by 3-4 percentage points in agriculture and underestimates the services by the same gap in both countries.

4 Counterfactual Analysis

After discussing the differences in the exogenous processes between India and China, calibrated in the previous section, I have established that these two countries were already on distinct paths by 1970. From the outset, India and China differed in key structural elements like their investment rates, the sectoral share of manufacturing in the value-added, consumption, and investment, and over time, their trajectories further diverged, particularly in terms of how sectoral total factor productivity (TFP) and trade evolved. In this section, I present the results of the counterfactual analysis, using the baseline model to examine the role of various factors that shaped the structural transformations of the two countries. This analysis allows us to isolate and better understand the impact of individual drivers, such as productivity growth and trade liberalization, on the economic evolution of both countries. By doing so, we can trace how differences in policy choices, external conditions, and sectoral dynamics contributed to their distinct development patterns, particularly the industrialization of China and the service-led growth in India.

4.1 Structural change in India

To understand the role of productivity growth and trade in the growth stories of IND, I run two versions of the model.

4.1.1 Role of International Trade

In the first counterfactual, I set IND in autarky by setting import and export costs too high for any trade to be feasible, keeping everything else the same as the baseline. This experiment filters out the impact of trade on sectoral allocation and growth over time.

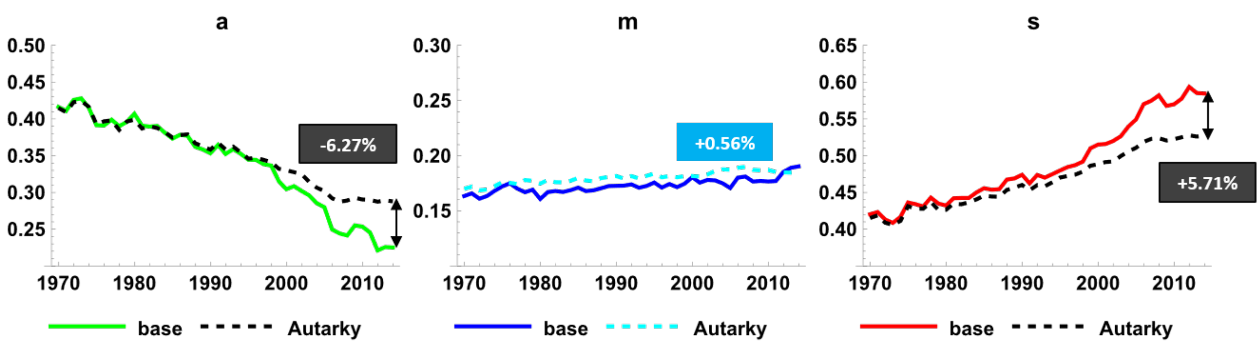

Figure 6: *Setting IND in Autarky (leveled by Autarky) compared with the baseline (labeled as a base) in all three sectors.*

As shown in Figure 6, International trade plays a significant role in the country's structural change, particularly after the mid-1990s, when India liberalized its trade policies. It accounts for a 6.27 percentage-point decline in agriculture share and a 5.71 percentage-point increase in services' share of the value-added. Although services are typically considered non-tradable, a substantial portion of India's growth in services can be attributed to trade. In contrast, the effect of trade on the manufacturing sector is relatively modest, contributing to only a 0.56 percentage-point increase in its share. There is a small interaction effect also on China's allocation. Trade with India contributed a modest 0.14 percentage-point gain in the Chinese manufacturing sector. The per-capita income would have been 9.8 percentage points higher in 2014 if India had remained in autarky.

4.1.2 Asymmetric Productivity Growth

In the second counterfactual, I set the Indian TFP fixed at the 1970 level, keeping the TFP in other countries the same as the baseline, in addition to no trade in India. The results are plotted in Figure 7.

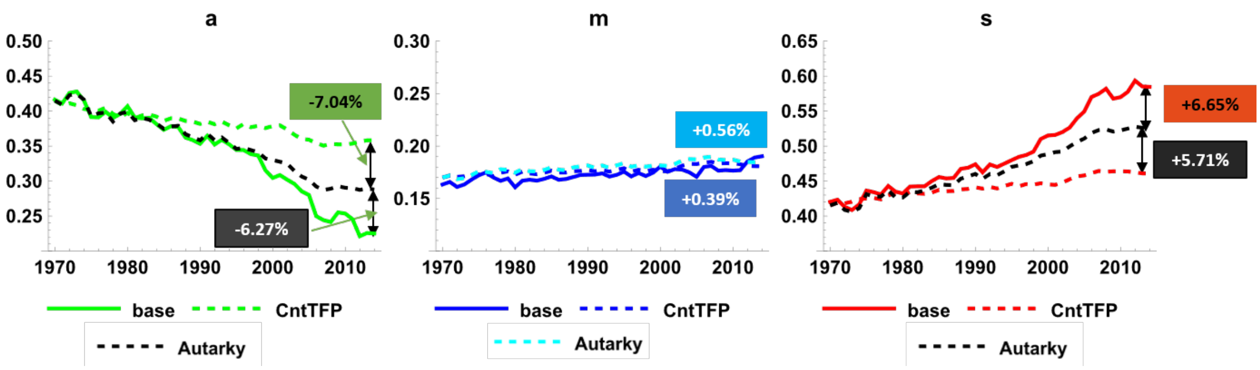

Figure 7: *Keeping The TFP at the 1970 level for IND in Autarky (labeled by CntTFP), are compared with the baseline in all three sectors.*

TFP alone contributes to a 7.04 percentage-point decline in the agricultural share, which is about 53% of the total decrease in the agriculture share in India till 2014. On the other hand, it increases the share of services by 6.65 percentage points, which accounts for 54% of the total gain of the services share over time. The TFP contributes to only a 0.39% share gain in manufacturing, which is 41% of the total change in the stagnant sector. TFP growth contributes to more than 50% of the transformation from agriculture to services in India. Also, with TFP growth, the per capita income would have been just 0.22 percentage points higher than what they were in 2014.

Nonetheless, three critical insights emerge here. First, trade has been pivotal in reshaping India's economic structure, especially in shifting from agriculture to services, despite India's trade openness index being 10-12 percentage points lower than China's post-liberalization. Second, without structural change, per capita income in 2014 would have been 9.6 percentage points higher, suggesting that the direct shift from agriculture to services has not improved welfare. Third, sluggish TFP growth has provided only a marginal boost to per capita income, while trade liberalization, implemented when productivity was weak, negatively impacted growth.

4.2 Structural change in China

I ran a similar counterfactual for China as I did for India in the previous subsection.

4.2.1 Role of International Trade

Placing China in autarky offers a valuable experiment—not only for understanding its own economic growth but also for assessing its indirect effects on the global economy. Many argue that China's extraordinary manufacturing growth has constrained growth opportunities for smaller economies worldwide. As shown in Figure 8, international trade contributes to about a 19% (2.43 percentage-point) decline in agriculture share and a 73% (2.85 percentage-point) increase in the manufacturing sector's share. In contrast to India, there is almost no role of trade in the services sector in China; rather, it would have slowed down the shift to services by 5% (0.43 percentage-point). Had there been no trade, China's per-capita income would have been 42.54% lower than what they were in 2014.

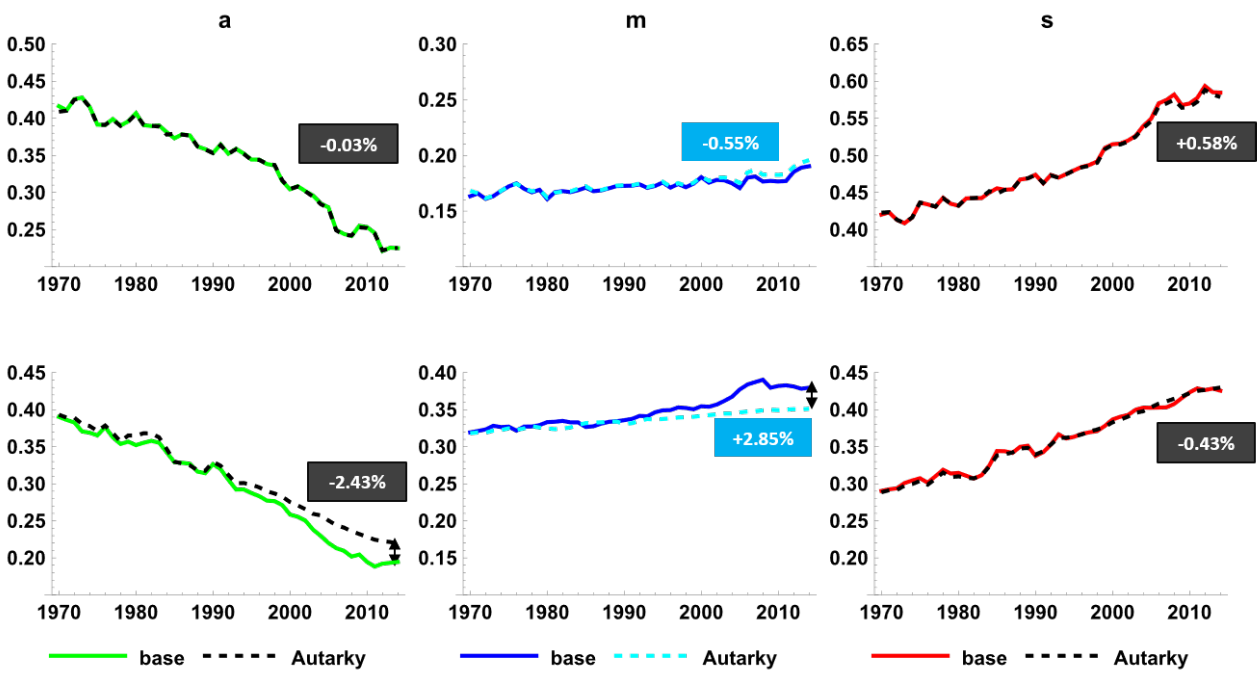

Figure 8: *Setting CHN in Autarky (leveled by Autarky) compared with the baseline (labeled as a base) in all three sectors.*

China's manufacturing growth is heavily reliant on trade, implying significant indirect effects on economies importing from China. Indian manufacturing, for instance, is negatively impacted by a 0.55 percentage-point reduction in sectoral share, reflecting almost the entire effect of trade observed in the previous section. However, India's per capita income remains nearly unaffected, while the Rest of the World's per capita income would have been only 0.14% higher in 2014 without China's growth. This suggests that China's expansion has, on balance, benefited other economies.

4.2.2 Role of Asymmetric Productivity Growth

Next, the Chinese TFP is set fixed at the first year (1970) level, keeping others the same as the baseline. The results are plotted in the bottom panel of Figure 9. In China, TFP causes a 10.61 percentage-point decline in agriculture share, which is 81% of the total decline during the period of the study. The manufacturing sector and services sector gained 1.05 percentage points and 9.56 percentage points, respectively, accounting for 27% and 105% of their transition over time. Chinese TFP has been growing much faster than the Indian TFP. Therefore, they contribute to faster transformation in shares, moving from agriculture to manufacturing and services.

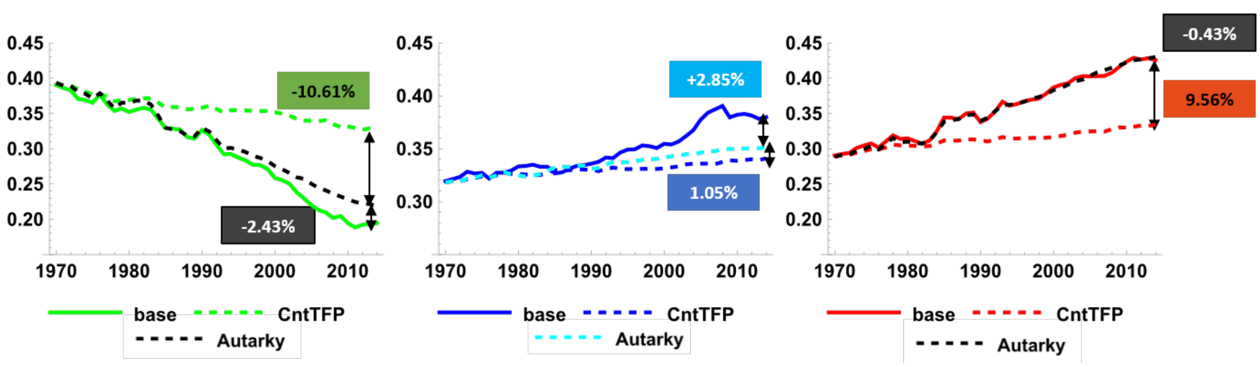

Figure 9: *Keeping The TFP at the 1970 level for CHN in Autarky (labeled by CntTFP), are compared with the baseline in all three sectors.*

Notably, TFP growth initially facilitated the shift of employment and value-added from agriculture to manufacturing and services, followed by trade, which played a crucial role in driving industrialization.

4.3 Replicating China Model for India

In another counterfactual experiment, I explored whether India's manufacturing sector would have expanded and its services sector reduced if Indian TFP had grown at the same rate as China's across all three sectors. It's worth noting that Chinese TFP has consistently outpaced

India's in both the manufacturing and services sectors, as shown in TFP calibration. The results, shown in Figure 10, indicate that agriculture would have declined similarly, with just a 0.95 percentage point higher share than in the baseline. Manufacturing would have gained an 8.11 percentage point share, while services' share would have decreased by 9.06 percentage points. Also, the per-capita income of India in 2014 would have increased by 137% of what it is in the baseline. India's dependence on manufacturing imports reduces; instead, its export share increases with all bilateral partners in the model. Therefore, sluggish TFP growth is a very crucial factor affecting not only the manufacturing growth in India but also the overall growth of the economy.

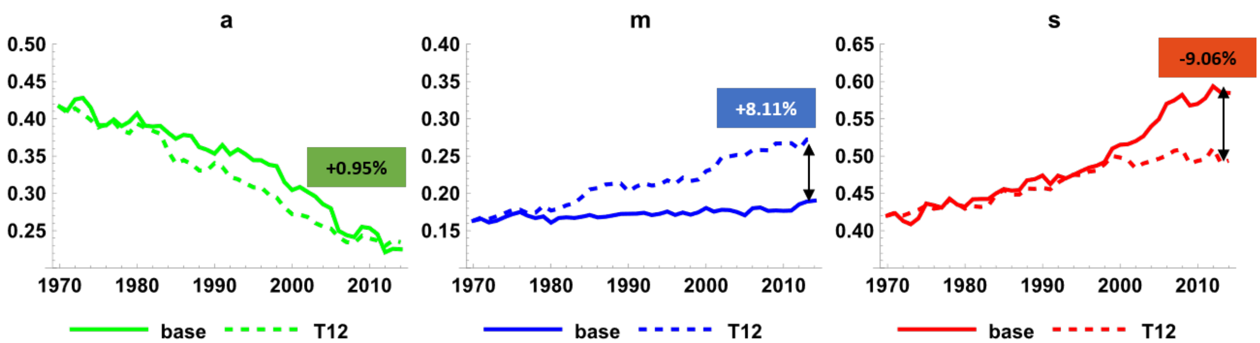

Figure 10: *Setting the Indian TFP growth rates equal to Chinese, keeping everything else, including trade cost, the same as the baseline (labeled as T12)*

In another counterfactual, further to setting the Indian TFP growth rate the same as the Chinese, I put the import cost of the ROW from IND the same as that from CHN, which further stimulates the structural transformation. It results in a faster decline in agriculture share, a hump-shaped growth in manufacturing with higher and early peaks, and, over time, a shift to services. This aberration in trade costs also affects the transformation in China, as their manufacturing starts declining earlier than they actually do, and the economic activities start moving towards the services sector. This implies that export-promoting policies and enhanced trade relationships in the form of more bilateral and multi-lateral trade partnerships can boost the growth of Indian manufacturing and also the overall economy.

5 Policy Experiment

This model can also help ascertain what should be done going forward to accelerate industrialization in India. The obvious question that arises is, can boosting TFP now when India is way behind the technological frontier still help in manufacturing growth? To find an answer to this, I did a conservative thought experiment wherein I used the model to project India's transformation path till 2030. This involved extrapolating the exogenous processes under a set of carefully defined assumptions, as detailed below:

- The labor endowment grew by 1.15% in IND, 0.54% in CHN, and 1.4% in ROW[1]
- The trade imbalances as a percent of GDP, the bilateral trade cost, and the preference shock processes remained the same as they were in 2014.
- The TFP for IND grew year-on-year at the rate of 3% in agri, 5% in manufg, and 4% in srvcs[2]. The TFP for CHN and ROW grew at their annualized growth rate between 1970-2014.

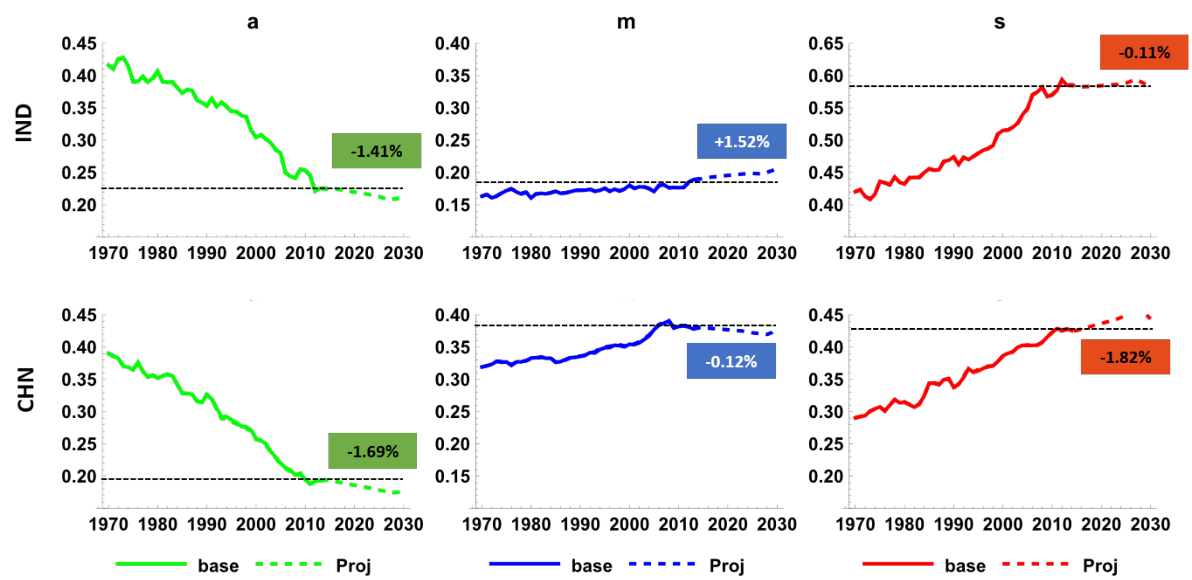

Figure 11: Projected structural transformation in India and China

The assumptions are very conservative. Indian TFP is likely to grow faster than the ones I assumed because of new policy reforms around skill development and greater emphasis

[1]approx average estimates of population growth rate taken from the World Bank data

[2]the rates are rounded off numbers of the rate of annualized TFP growth rate of CHN between 1970-2014

on research and development. Significant infrastructure development is undergoing in the country. Rising FDI flows are also going to play an important role.

The conservative estimates also show the rising share of manufacturing in the economy. As shown in figure 11, all the reduction in the agriculture sector is absorbed by the manufacturing sector in India. The sectoral share of manufacturing increases by 1.52% percentage points. There is no significant rise in the services sector; instead, its share declines marginally. Whereas, in China, we see a broad hump shape appearing, though quite slowly. The manufacturing share declines by only a 0.12% point. The services sector gains and starts getting more prominent. Also, the GDP grows by 50% in India and China both during this extended period.

This experiment also confirms the claim that Indian manufacturing is yet to take off and is on the path of slow growth toward industrialization. The claims of premature deindustrialization seem premature in the context of India.

6 Conclusion

The calibrated parameters and processes confirm that since 1970, China and India have followed distinct paths in their sectoral composition of value-added, consumption, and investment demand. China's economy has been predominantly manufacturing-driven, while India's has been more service-oriented. The counterfactual analysis shows that China's rapid TFP growth, combined with a high investment rate, has driven approximately 80% of its shift out of agriculture, with international trade accounting for the remaining 20%. In contrast, both TFP growth and trade have contributed equally to shifting economic activity away from agriculture toward services in India's transformation. The difference seems even more stark when we look at the trade openness index, in which India was, on average, 10-12 percent lower than China after 1980. Notably, India's services sector, despite being traditionally considered non-tradeable, has a significant trade component. However, despite these shifts, India's overall economy remains considerably smaller than China's. Another noteworthy aspect of structural transformation is that economies opening up to trade after a boost in productivity have benefited from export-led growth. China, South Korea, and many other industrialized nations have had this advantage. In contrast, those that liberalized trade at an early stage without substantial productivity gains have struggled, as strong adverse import effects have outweighed the positive impact of exports.

Shutting down the trade from and to China, in one of the counterfactuals in the model, did not lead to more manufacturing in India or significantly more growth in India or the Rest of the World. This tells us that China's growth alone does not explain the stagnant or premature deindustrialization in other developing countries. Since the trade is driven by comparative advantage in the model and comparative advantage depends on productivity, the analysis puts significant weight on improving productivity at the early stage of development for growth.

Setting India's sectoral TFP growth rate equal to China's would result in a 1.5-fold increase in India's manufacturing share, highlighting the critical role of TFP growth for the sector. Additionally, per capita income would rise by more than double (137%), underscoring the importance of manufacturing growth for the overall economy. This suggests that Indian manufacturing hasn't declined prematurely but instead has yet to take off, provided the right policies are implemented. In another counterfactual, where I not only equalized India's TFP growth with China's but also set the import cost of ROW from India to match that from China, the transformation aligns more closely with a traditional structural change, featuring a hump-shaped manufacturing growth followed by a gradual shift toward services. Therefore, a focus on improving TFP coupled with export-promoting policies will lead to manufacturing growth in India.

Going forward, the TFP boost increases the role of manufacturing in the economic growth of India, even by conservative estimates. This reinforces the view that Indian manufacturing is gradually progressing toward industrialization. The notion of premature deindustrialization appears, in this context, to be itself a bit premature.

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A Data

To take my model to the data, I require a 3-country, 3-sector time series. The time period for the analysis is 1970-2014. Three countries are India, China and ROW where ROW is an aggregate of the 56 countries representing a comprehensive mix of all continents and income categories (20 rich countries from Europe and others (Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom, and the United States), 11 Asian Countries (Egypt, Hong Kong, Indonesia, Japan, Malaysia, Mauritius, Philippines, Singapore, South Korea, Taiwan, and Thailand), 7 Latin American countries (Bolivia, Argentina, Chile, Colombia, Costa Rica, Mexico, and Peru) and 18 African countries (Botswana, Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Lesotho, Malawi, Morocco, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Uganda, and Zambia)). I aggregate the data into three sectors: Agriculture, Manufacturing, and Services. The sectors are defined per the International Standard Industrial Classification of all Economic Activities, Revision 4 code definitions[3]. Agriculture includes agriculture, hunting, forestry, fishing (A), mining, and quarrying (B). The manufacturing is an aggregate of manufacturing (C) and Electricity, Gas, and Water Supply (DtE). Service is an aggregate of all other sectors from F to U. The specific list of sectors is as follows.

EUKLEMS and GGDC-ETD: I used the 2009 and 2017 EUKLEMS releases[4] to build the data on VA at current prices, VA at constant prices (Quantity Index), and people employed for 1970-2014 at the three-sector level. Since EUKLEMS consists of data for only EU countries, I complement the data with the Economic Transformation Database linked Historic Series[5] De Vries et al. (2021) obtained from GGDC to complete the sample of 56 countries. Some countries have missing data for a few years, and those are filled using linear interpolation. Both sources provide data in national currencies, so they are converted into PPP units before any aggregation. In the absence of sectoral PPP, data on PPP exchange rate GDP is used to convert the sectoral VA, assuming that aggregate PPP is a good proxy for the sectoral PPP. PPP data is obtained from the OECD and the World Bank database.

VA at current prices and employment data can be simply collapsed by summing them

[3]https://unstats.un.org/unsd/classifications/Family/Detail/27

[4]http://www.euklems.net/index.html and http://www.euklems.net/index_TCB_201807.shtml

[5]https://www.rug.nl/ggdc/structuralchange/etd/

Table 8: List of sectors

Agriculture	Manufacturing	Services
Agriculture	Food, Beverages and Tobacco	Construction
Hunting	Textiles, Leather and Footwear	Wholesale and Retail Trade
Forestry and Fishing	Pulp, Paper, Printing, & Publishing	Hotels and Restaurants
Mining and Quarrying	Coke, Refined Petro & Nuclear Fuel	Transport and Storage
	Chemicals and Chemical Products	Post and Telecommunications
	Rubber and Plastics	Financial Intermediation
	Other Non-Metallic Mineral	Real Estate and Renting
	Basic Metals and Fabricated Metal	Business Activities
	Machinery, Nec	Community, Social
	Electrical and Optical Equipment	& Personal Services
	Transport Equipment	
	Manufacturing, Nec; Recycling	
	Electricity, Gas and Water Supply	

over across sectors and countries to get the required model sectors and countries. However, the Real value-added series (VA at constant 2005 prices) is aggregated using the Tornqvist Method.

GGDC Productivity Level Database: I use the GGDC PLD 2005 benchmark database[6] to obtain the sectoral PPP VA prices to make VA prices comparable across countries.

World Input-Output Tables: I use all three sets of WIOT. The long-run WIOD (LR-WIOD) version 1.1[7] released in 2022 Woltjer et al. (2021) contains data for 25 countries and the ROW from 1965-2000. The WIOD 2013 release contains data for 27 EU countries and 13 other major countries and an aggregate for the rest of the world for 1995-2011. The WIOD 2016 release[8] Timmer et al. (2015) contains data for 43 countries and ROW for 2000-2014. There are certain differences in the methodology of the two releases: differences in the price concepts (producer prices in LR-WIOT versus basic prices in the others), differences in

[6]Robert Inklaar and Marcel P. Timmer (2014), "The Relative Price of Services" Review of Income and Wealth 60(4): 727–746

[7]Woltjer, P., Gouma, R. and Timmer, M. P. (2021), "Long-run World Input-Output Database: Version 1.1 Sources and Methods", GGDC Research Memorandum 190

[8]Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), "An Illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production", Review of International Economics., 23: 575–605

the SNA version (SNA 2008 in the 2016 release, SNA 1993 in the others); in the industrial classification (ISIC rev.4 in the 2016 release versus rev 3.1 in the others) and in the level of industry detail. This precludes comparability at a detailed level. Yet, for analyses at a more aggregate trends and levels are likely to be comparable and could be used side-by-side. Since I am aggregating at the level of three major sectors, the industry classification is not an issue. However, the difference is the price concept makes the data from the two sources incomparable. First, I collapse all countries other than IND and CHN as ROW in all three series and then splice them using common years to make them comparable. Thus, I obtain a consistent country-wise Input-output table in millions of USD at current prices for 3 countries in my analysis.

Thus obtained time series is then used to calculate all the production side parameters like value-added share parameters, intermediate-share parameters, bilateral trade shares, and the global investment ratio (Net Export to GDP ratio). I also use the sectoral consumption and investment expenditure ratio data to calibrate the consumption demand and investment demand elasticity and share-shift parameters.

Since, I have only 54 countries in my dataset as the aggregate of the ROW, this is not consistent with the ROW in WIOT (contains all countries in the world). I use the GDP weights of the countries to make the ROW from WIOT consistent with my sample. I use only the ratios from this dataset.

Penn World Table: I refer to the Penn World Table Feenstra et al. (2015) for the aggregate consumption and investment expenditure and capital stock. The PWT 8.1 release provides data for the Real consumption of households and government at current PPPs (in mil. 2005USD), Real domestic absorption (real consumption plus investment) at current PPPs (in mil. 2005USD), and capital stock at current PPPs (in million 2005 USD). I collected the data for the sample for 54 countries and then aggregated it in 3 model countries. The data is available till 2011 only, so the last three years are extrapolated.

I also refer to OECD[9] and World Bank Database[10] for the data on the annual exchange rate and PPP exchange rate for GDP.

[9]https://data-explorer.oecd.org

[10]https://data.worldbank.org/indicator/PA.NUS.PPP

B Equilibrium Conditions

1. **FIRM**

Marginal Condition for Capital: $R_{ikt}K_{ikt} = \nu\phi_{ik}P_{ikt}Y_{ikt}$ (F1)

Marginal Condition for labor: $W_{ikt}L_{ikt} = (1-\nu)\phi_{ik}P_{ikt}Y_{ikt}$ (F2)

Marginal Condition for Intermediate: $P_{int}M_{iknt} = \gamma_{ikn}(1-\phi_{ik})P_{ikt}Y_{ikt}$ (F3)

Unit Variable cost: $$V_{ikt} = \left(\frac{R_{it}}{\nu\phi_{ik}}\right)^{\nu\phi_{ik}}\left(\frac{W_{it}}{(1-\nu)\phi_{ik}}\right)^{(1-\nu)\phi_{ik}}\left(\frac{\prod_{n=a,m,s}\left(\frac{P_{int}}{\gamma_{ikn}}\right)^{\gamma_{ikn}}}{1-\phi_{ik}}\right)^{1-\phi_{ik}} \quad \text{(F4)}$$

Trade Cost: $$d_{ijkt} = \mathbf{Max}\left[\left(\frac{\pi_{ijkt}}{\pi_{jjkt}}\right)\left(\frac{P_{ikt}}{P_{jkt}}\right), 1\right] \quad \text{(F5)}$$

Sectoral prices: $$P_{ikt} = \xi\left(\sum_{j=1,2,3}(T_{jkt}^{-\phi_{ik}}V_{jkt}d_{ijkt})^{-\theta}\right)^{-1/\theta} \quad \text{(F6)}$$

Trade share: $$\pi_{jikt} = \frac{(T_{ikt}^{-\phi_{ik}}V_{ikt}d_{jikt})^{-\theta}}{\Phi_{jkt}} = \frac{(T_{ikt}^{-\phi_{ik}}V_{ikt}d_{jikt})^{-\theta}}{\sum_{i=1,2,3}(T_{ikt}^{-\phi_{ik}}V_{ikt}d_{jikt})^{-\theta}} \quad \text{(F7)}$$

2. **HOUSEHOLDS: Intra-temporal Equilibrium**

Investment Demand: $$X_{ikt} = L_{it}\omega_k^x\left(\frac{X_{it}}{L_{it}}\right)^{(1-\sigma_x)\epsilon_k^x+\sigma_x}\left(\frac{P_{ikt}}{P_{it}^x}\right)^{-\sigma_x} \quad \text{(H1)}$$

Investment Price Index: $$P_{it}^x = \left(\sum_k \omega_k^x\left(\frac{X_{it}}{L_{it}}\right)^{(1-\sigma_x)(\epsilon_k^x-1)}P_{ikt}^{1-\sigma_x}\right)^{\frac{1}{1-\sigma_x}} \quad \text{(H2)}$$

Consumption demand: $$C_{ikt} = L_{it}\omega_k^c\left(\frac{C_{it}}{L_{it}}\right)^{(1-\sigma_c)\epsilon_k^c+\sigma_c}\left(\frac{P_{ikt}}{P_{it}^c}\right)^{-\sigma_c} \quad \text{(H3)}$$

Consumption Price Index: $$P_{it}^c = \left(\sum_k \omega_k^c\left(\frac{C_{it}}{L_{it}}\right)^{(1-\sigma_c)(\epsilon_k^c-1)}P_{ikt}^{1-\sigma_c}\right)^{\frac{1}{1-\sigma_c}} \quad \text{(H4)}$$

Period Budget Constraint: $P_{it}^cC_{it} + P_{it}^xX_{it} = (1-\alpha_{it})\big(R_{it}K_{it} + W_{it}L_{it}\big) + L_{it}T_t^G$ (H5)

3. **HOUSEHOLDS: Inter-temporal Equilibrium**

Capital Accumulation: $K_{it+1} = (1-\delta)K_{it} + X_{it}^{\lambda}\big(\delta K_{it}\big)^{1-\lambda}$ (H6)

Euler Equation: $$\frac{C_{it+1}/L_{it+1}}{C_{it}/L_{it}} = \beta\left(\frac{\psi_{it+1}}{\psi_{it}}\right)\left(\frac{(1-\alpha_{it+1})\frac{R_{it+1}}{P_{it+1}^x} - X_2(K_{it+2},K_{it+1})}{X_1(K_{it+1},K_{it})}\right)\left(\frac{P_{it+1}^x/P_{it+1}^c}{P_{it}^x/P_{it}^c}\right) \quad \text{(H7)}$$

Derivative of X_{it} w.r.t K_{it+1}: $$X_1(K_{it+1},K_{it}) = \frac{\delta^{1-\frac{1}{\lambda}}}{\lambda}\left(\frac{K_{it+1}}{K_{it}} - (1-\delta)\right)^{\frac{1-\lambda}{\lambda}} \quad \text{(H8)}$$

Derivative of X_{it} w.r.t K_{it}: $$X_2(K_{it+1},K_{it}) = X_1(K_{it+1},K_{it})\left((\lambda-1)\frac{K_{it+1}}{K_{it}} - \lambda(1-\delta)\right) \quad \text{(H9)}$$

4. **MARKET CLEARING CONDITIONS**

Goods Mkt: $$Q_{ikt} = C_{ikt} + X_{ikt} + \sum_{n=a,m,s} \left((1-\phi_{in})\gamma_{ink} \sum_{j=1,2,3} \left(\pi_{jint} \frac{P_{jnt}Q_{jnt}}{P_{ikt}} \right) \right) \tag{M1}$$

Labor Mkt: $$\sum_{k=a,m,s} \left((1-\nu)\phi_{ik} \sum_{j=1,2,3} \left(\pi_{jikt} P_{jkt} Q_{jkt} \right) \right) = W_{it} L_{it} \tag{M2}$$

Capital Mkt: $$\sum_{k=a,m,s} \left(\nu\phi_{ik} \sum_{j=1,2,3} \left(\pi_{jikt} P_{jkt} Q_{jkt} \right) \right) = R_{it} K_{it} \tag{M3}$$

Global Investment: $$\sum_{i=1,2,3} \alpha_{it}(R_{it}K_{it} + W_{it}L_{it}) = \sum_{i=1,2,3} L_{it} T_t^G \tag{M4}$$

C Algorithm for the Numerical Solution

1. Guess a IxT matrix of nominal Investment rates $\rho_{\mathbf{t}}$ defined as following

$$\rho_{it} = \frac{P^x_{it} X_{it}}{R_{it} K_{it} + W_{it} L_{it}}$$

2. Solve for period equilibrium: At the beginning of every period, the capital stock for each country K_{it} is known.

   (a) Make a guess of wages W_i for $i = 2, 3$ such that $W_1 = 1$ (numeraire).

      i. Calculate R_i such that both labor and capital markets clear using F1, F2, M2 and M3.

      ii. Given W_i and R_i, solve the first set of nine simultaneous equations to pin down sectoral prices

         A. Compute Unit variable cost and trade cost using equations F4 and F5.

         B. Solve the 3x3 pricing equations F6 simultaneously to pin down sectoral prices.

         C. Use the sectoral prices to compute the sectoral bilateral trade shares using F7.

      iii. Given the sectoral prices, calculate the Investment Price Index and the aggregate investment using the guessed value of ρ_{it} from step 1 and H2.

      iv. Compute sectoral investment demand using H1.

      v. Compute T^G_t using M4.

      vi. Solve H4 and H5 simultaneously to pin down C_{it} and P^c_{it}.

      vii. Compute sectoral consumption demand C_{ikt} using H3.

      viii. Solve nine simultaneous equations coming from M1 to pin down all Qs.

   (b) Calculate total labor demand given the sectoral Qs for each country using M2 and check if labor markets in countries 2 and 3 are clear. If not, repeat step (a) after updating the initial guess of W_i for $i = 2, 3$ till markets clear.

   (c) Compute k_{it+1} using H6.

   (d) Compute X_1 and X_2 using H8 and H9.

3. Return to step 2 and do it for all periods.

4. Given a sequence of prices and consumption, investment, and capital quantities, check whether the Euler equation H7 satisfies. If not, then update the guess values of ρ_{it} and repeat steps 2 and 3 till Euler equations are satisfied in all periods.

D Model Derivations

D.1 Households' Problem

D.1.1 Period-wise Utility Maximization

$$\mathcal{L} = \frac{C_{it}}{L_{it}} + \mu_1 \left[1 - \sum_k (\omega_k^c)^{\frac{1}{\sigma}} \left(\frac{C_{it}}{L_{it}} \right)^{\frac{1-\sigma_c}{\sigma_c}\epsilon_k^c} \left(\frac{C_{ikt}}{L_{it}} \right)^{\frac{\sigma_c - 1}{\sigma_c}} \right] + \mu_2 \left[P_{it} C_{it} - \sum_k P_{ikt} C_{ikt} \right]$$

First Order Condition with respect to C_{ikt}:

$$\mu_1 \frac{\sigma_c - 1}{\sigma_c} (\omega_k^c)^{\frac{1}{\sigma}} \left(\frac{C_{it}}{L_{it}} \right)^{\frac{1-\sigma_c}{\sigma_c}\epsilon_k^c} \left(\frac{C_{ikt}}{L_{it}} \right)^{\frac{\sigma_c - 1}{\sigma_c}} = \mu_2 P_{ikt} C_{ikt}$$

Summing over all sectors on both sides of the equations

$$\mu_1 \frac{\sigma_c - 1}{\sigma_c} \underbrace{\sum_k (\omega_k^c)^{\frac{1}{\sigma}} \left(\frac{C_{it}}{L_{it}} \right)^{\frac{1-\sigma_c}{\sigma_c}\epsilon_k^c} \left(\frac{C_{ikt}}{L_{it}} \right)^{\frac{\sigma_c - 1}{\sigma_c}}}_{=1} = \mu_2 \underbrace{\sum_s P_{ikt} C_{ikt}}_{P_{it}^c C_{it}} \Rightarrow \frac{\mu_1}{\mu_2} \left(\frac{\sigma_c - 1}{\sigma_c} \right) = P_{it}^c C_{it}$$

Which implies

$$(\omega_k^c)^{\frac{1}{\sigma}} \left(\frac{C_{it}}{L_{it}} \right)^{\frac{1-\sigma_c}{\sigma_c}\epsilon_k^c} \left(\frac{C_{ikt}}{L_{it}} \right)^{\frac{\sigma_c - 1}{\sigma_c}} = \frac{P_{ikt} C_{ikt}}{P_{it}^c C_{it}}$$

Rearranging the terms

$$C_{ikt} = L_{it} \omega_k^c \left(\frac{C_{it}}{L_{it}} \right)^{(1-\sigma_c)\epsilon_k^c + \sigma_c} \left(\frac{P_{ikt}}{P_{it}^c} \right)^{-\sigma_c}$$

D.1.2 Aggregate Consumption Price Index

Multiplying the sectoral consumption allocation both sides by $\frac{p_{kt}}{P_t}$, and also multiply and divide RHS by C_t

$$P_{ikt} C_{ikt} = \omega_k^c \left(\frac{C_{it}}{L_{it}} \right)^{(1-\sigma_c)\epsilon_k^c + \sigma_c - 1} \left(\frac{P_{ikt}}{P_{it}^c} \right)^{1-\sigma_c} P_{it} C_{it}$$

Summing it over all sectors on both sides of the equations

$$\underbrace{\sum_k P_{ikt} C_{ikt}}_{P_{it}^c C_{it}} = P_{it}^c C_{it} \left(\frac{1}{P_{it}^c} \right)^{1-\sigma_c} \sum_k \omega_k^c \left(\frac{C_{it}}{L_{it}} \right)^{(1-\sigma_c)(\epsilon_k^c - 1)} P_{ikt}^{1-\sigma_c}$$

Therefore, the aggregate price index for consumption goods is:

$$P_{it}^c = \left(\sum_k \omega_k^c \left(\frac{C_{it}}{L_{it}} \right)^{(1-\sigma_c)(\epsilon_k^c - 1)} P_{ikt}^{1-\sigma_c} \right)^{\frac{1}{1-\sigma_c}}$$

D.1.3 Gross Growth rate of Aggregate Consumption Price Index

To find the gross growth rate of the price index, first, I shift the exponents from the right-hand side to the left-hand side:

$$(P_{it}^c)^{1-\sigma_c} = \sum_k \omega_k^c P_{ikt}^{1-\sigma_c} \Big(\frac{C_{it}}{L_{it}}\Big)^{(1-\sigma_c)(\epsilon_k^c - 1)}$$

Dividing both sides by $(P_{it-1}^c)^{1-\sigma_c}$

$$\Big(\frac{P_{it}^c}{P_{it-1}^c}\Big)^{1-\sigma_c} = \sum_k \omega_k^c \Big(\frac{P_{ikt}}{P_{it-1}^c}\Big)^{1-\sigma_c} \Big(\frac{C_{it}}{L_{it}}\Big)^{(1-\sigma_c)(\epsilon_k^c - 1)}$$

Multiply and divide RHS by $P_{ikt-1}^{1-\sigma_c}$ and $\frac{C_{it-1}}{L_{it-1}}$ to the appropriate power

$$\Big(\frac{P_{it}^c}{P_{it-1}^c}\Big)^{1-\sigma_c} = \sum_k \underbrace{\omega_k^c \Big(\frac{P_{ikt-1}}{P_{it-1}^c}\Big)^{1-\sigma_c} \Big(\frac{C_{it-1}}{L_{it-1}}\Big)^{(1-\sigma_c)(\epsilon_k^c - 1)}}_{\frac{P_{ikt-1}C_{ikt-1}}{P_{it-1}C_{it-1}} \equiv e_{ikt-1}} \Big(\frac{P_{ikt}}{P_{ikt-1}}\Big)^{1-\sigma_c} \frac{\Big(\frac{C_{it}}{L_{it}}\Big)^{(1-\sigma_c)(\epsilon_k^c - 1)}}{\Big(\frac{C_{it-1}}{L_{it-1}}\Big)^{(1-\sigma_c)(\epsilon_k^c - 1)}}$$

Substituting for the sectoral consumption share e_{ikt}

$$\dot{P}_{it}^c = \Bigg(\sum_k e_{ikt-1} \dot{P}_{ikt}^{1-\sigma_c} \Big(\frac{\dot{C}_{it}}{\dot{L}_{it}}\Big)^{(1-\sigma_c)(\epsilon_k^c - 1)}\Bigg)^{\frac{1}{1-\sigma_c}}$$

D.1.4 Consumption Expenditure

Multiplying the aggregate consumption price index equation by C_{it}/L_{it}

$$\frac{E_{it}}{L_{it}} = \frac{P_{it}^c C_{it}}{L_{it}} = \Bigg(\sum_k \omega_k^c \Big(\frac{C_{it}}{L_{it}}\Big)^{(1-\sigma_c)\epsilon_k^c} P_{ikt}^{1-\sigma_c}\Bigg)^{\frac{1}{1-\sigma_c}}$$

Similarly, by multiplying both sides of the gross growth rate of the consumption price index equation by $\dot{C}_{it}/\dot{L}_{it}$, we get a one-period deviation of the total consumption expenditure per capita.

$$\frac{\dot{E}_{it}}{\dot{L}_{it}} = \Bigg(\sum_k e_{ikt-1} \dot{P}_{ikt}^{1-\sigma_c} \Big(\frac{\dot{C}_{it}}{\dot{L}_{it}}\Big)^{(1-\sigma_c)\epsilon_k^c}\Bigg)^{\frac{1}{1-\sigma_c}}$$

D.1.5 Share-shift parameters

Multiplying the sectoral consumption allocation both sides by $\frac{p_{kt}}{P_t}$, and also multiply and divide RHS by C_t

$$P_{ikt}C_{ikt} = \omega_k^c \Big(\frac{C_{it}}{L_{it}}\Big)^{(1-\sigma_c)\epsilon_k^c + \sigma_c - 1} \Big(\frac{P_{ikt}}{P_{it}^c}\Big)^{1-\sigma_c} P_{it}C_{it}$$

$$\frac{E_{ikt}}{E_{it}} = \frac{P_{ikt}C_{ikt}}{P_{it}C_{it}} = \omega_k^c \Big(\frac{C_{it}}{L_{it}}\Big)^{(1-\sigma_c)(\epsilon_k^c - 1)} \Big(\frac{P_{ikt}}{P_{it}^c}\Big)^{1-\sigma_c}$$

$$\omega_k^c = \frac{E_{ikt}}{E_{it}} \left(\left(\frac{C_{it}}{L_{it}}\right)^{(\epsilon_k^c - 1)} \left(\frac{P_{ikt}}{P_{it}^c}\right) \right)^{\sigma_c - 1}$$

Summing them over all sectors and substituting for $C_{it} = E_{it}/P_{it}^c$, the resulting equation has just one unknown variable P_{it}^c.

$$1 = \sum_{k=a,m,s} \omega_k^c = \sum_{k=a,m,s} \left(\frac{E_{ikt}}{E_{it}}\right) \left(\frac{P_{ikt}}{(P_{it}^c)^{\epsilon_k^c}} \left(\frac{\hat{E}_{it}}{\hat{L}_{it}}\right)^{\epsilon_k^c - 1} \right)^{\sigma_c - 1}$$

D.1.6 Aggregate Investment and Price Index

The aggregate investment demand has the same formulation as aggregate consumption demand, so all derivation follows the same steps.

$$X_{ikt} = L_{it}\omega_k^x \left(\frac{X_{it}}{L_{it}}\right)^{(1-\sigma_x)\epsilon_k^x + \sigma_x} \left(\frac{P_{ikt}}{P_{it}^x}\right)^{-\sigma_x}$$

$$P_{it}^x = \left(\sum_k \omega_k^x \left(\frac{X_{it}}{L_{it}}\right)^{(1-\sigma_x)(\epsilon_k^x - 1)} P_{ikt}^{1-\sigma_x} \right)^{\frac{1}{1-\sigma_x}}$$

The elasticities and the share-shift parameters are also derived using similar formulations.

D.1.7 Investment and Capital Accumulation

$$K_{it+1} = (1-\delta)K_{it} + X_{it}^{\lambda}\big(\delta K_{it}\big)^{1-\lambda}$$

Solving for X_{it}

$$X_{it}^{\lambda} = \frac{K_{it+1} - (1-\delta)K_{it}}{(\delta K_{it})^{1-\lambda}} \Rightarrow \delta^{\lambda-1}\left(\frac{K_{it+1}}{K_{it}} - (1-\delta)\right)K_{it}^{\lambda} = X_{it}^{\lambda}$$

$$X_{it}(K_{it+1}, K_{it}) \equiv X_{it} = \delta^{1-\frac{1}{\lambda}}\left(\frac{K_{it+1}}{K_{it}} - (1-\delta)\right)^{\frac{1}{\lambda}} K_{it}$$

D.1.8 Intertemporal households' Problem

Households maximize their lifetime utility (1a), given the period-wise budget constraint (1e).

$$\mathcal{L} = \sum_{t=1}^{\infty} \beta^{t-1}\psi_{it}L_{it}\ln\left(\frac{C_{it}}{L_{it}}\right) - \sum_{t=1}^{\infty} \mu_t\beta^{t-1}\left[P_{it}^c C_{it} + P_{it}^x X_{it} - (1-\alpha_{it})\big(R_{it}K_{it} + W_{it}L_{it}\big) - L_{it}T_t^G\right]$$

First Order Conditions

$$\mathbf{C_{it}}: \quad \beta^{t-1}\psi_{it}\left(\frac{L_{it}}{C_{it}}\right) = \mu_t\beta^{t-1}P_{it}^c$$

$$\frac{C_{it+1}/L_{it+1}}{C_{it}/L_{it}} = \frac{\mu_t}{\mu_{t+1}}\left(\frac{\psi_{it+1}}{\psi_{it}}\frac{P_{it}^c}{P_{it+1}^c}\right)$$

$$\mathbf{K_{it+1}}: \quad \mu_t \beta^{t-1} P^x_{it} X_1(K_{it+1}, K_{it}) = \mu_{t+1}\beta^t \Big(- P^x_{it+1} X_2(K_{it+2}, K_{it+1}) + (1-\alpha_{it+1}) R_{it+1} \Big)$$

$$\frac{\mu_t}{\mu_{t+1}} = \beta \frac{(1-\alpha_{it+1})R_{it+1} - P^x_{it+1} X_2(K_{it+2}, K_{it+1})}{P^x_{it} X_1(K_{it+1}, K_{it})}$$

Combining the two first orders conditions

$$\frac{C_{it+1}/L_{it+1}}{C_{it}/L_{it}} = \beta \Big(\frac{\psi_{it+1}}{\psi_{it}}\Big) \left(\frac{(1-\alpha_{it+1})\frac{R_{it+1}}{P^x_{it+1}} - X_2(K_{it+2}, K_{it+1})}{X_1(K_{it+1}, K_{it})} \right) \left(\frac{P^x_{it+1}/P^c_{it+1}}{P^x_{it}/P^c_{it}} \right)$$

where X_1 is the derivative of investment w.r.t. next period capital $K_{i,t+1}$ and X_2 is the derivative of investment w.r.t. current period capital K_{it}

$$X_1(K_{it+1}, K_{it}) = \frac{\delta^{1-\frac{1}{\lambda}}}{\lambda} \Big(\frac{K_{it+1}}{K_{it}} - (1-\delta) \Big)^{\frac{1-\lambda}{\lambda}}$$

$$X_2(K_{it+1}, K_{it}) = -X_1(K_{it+1}, K_{it}) \frac{K_{it+1}}{K_{it}} + \lambda X_1(K_{it+1}, K_{it}) \Big(\frac{K_{it+1}}{K_{it}} - (1-\delta) \Big)$$

$$X_2(K_{it+1}, K_{it}) = X_1(K_{it+1}, K_{it}) \Big((\lambda - 1) \frac{K_{it+1}}{K_{it}} - \lambda(1-\delta) \Big)$$

D.2 Firms' Problem

D.2.1 Firms' profit maximization problem

$$\max_{K_{ik} L_{ik}, M_{ikn}} P_{ik} \left[A_{ik} \big(K^{\nu}_{ik} L^{(1-\nu)}_{ik} \big)^{\phi_{ik}} \Big(\prod_{n=a,m,s} M^{\gamma_{ikn}}_{ikn} \Big)^{1-\phi_{ik}} \right] - R_i K_{ik} - W_i L_{ik} - \sum_{n=\{a,m,s\}} \Big[P_{in} M_{ikn} \Big]$$

First Order Conditions

$$R_i K_{ik} = \nu \phi_{ik} P_{ik} Y_{ik}$$

$$W_i L_{ik} = (1-\nu) \phi_{ik} P_{ik} Y_{ik}$$

$$P_{in} M_{ikn} = \gamma_{ikn} (1-\phi_{ik}) P_{ik} Y_{ik}$$

Using the first-order conditions

$$P_{ik} = \frac{1}{A_{ik}} \left(\frac{R_i}{\nu \phi_{ik}} \right)^{\nu \phi_{ik}} \left(\frac{W_i}{(1-\nu)\phi_{ik}} \right)^{(1-\nu)\phi_{ik}} \left(\frac{\prod_{n=a,m,s} \left(\frac{P_{in}}{\gamma_{ikn}} \right)^{\gamma_{ikn}}}{1-\phi_{ik}} \right)^{1-\phi_{ik}} \equiv \frac{V_{ik}}{A_{ik}}$$

D.2.2 Mapping the GO-prices to VA-prices

Substituting for M_{ikn} from the first order condition to the Production function;

$$Y_{ik} = A_{ik} \left(K^{\nu}_{ik} L^{(1-\nu)}_{ik} \right)^{\phi_{ik}} \left(\prod_{n=a,m,s} \left(\frac{\gamma_{ikn}(1-\phi_{ik}) P_{ik} Y_{ik}}{P_{in}} \right)^{\gamma_{ikn}} \right)^{1-\phi_{ik}}$$

$$Y_{ik} = P_{ik}^{\frac{1-\phi_{ik}}{\phi_{ik}}} \left((1-\phi_{ik}) \prod_{n=\{a,m,s\}} \left(\frac{\gamma_{ikn}}{P_{in}} \right)^{\gamma_{ikn}} \right)^{\frac{1-\phi_{ik}}{\phi_{ik}}} A_{ik}^{\frac{1}{\phi_{ik}}} \left(K_{ik}^{\nu} L_{ik}^{1-\nu} \right)$$

Multiplying both sides by $\phi_{ik} P_{ik}$

$$\underbrace{\phi_{ik} P_{ik} Y_{ik}}_{\text{value-added}} = \phi_{ik} P_{ik}^{\frac{1}{\phi_{ik}}} \left((1-\phi_{ik}) \prod_{n=\{a,m,s\}} \left(\frac{\gamma_{ikn}}{P_{in}} \right)^{\gamma_{ikn}} \right)^{\frac{1-\phi_{ik}}{\phi_{ik}}} A_{ik}^{\frac{1}{\phi_{ik}}} \left(K_{ik}^{\nu} L_{ik}^{1-\nu} \right)$$

$$\underbrace{\left(\frac{\phi_{ik} P_{ik} Y_{ik}}{A_{ik}^{\frac{1}{\phi_{ik}}} \left(K_{ik}^{\nu} L_{ik}^{1-\nu} \right)} \right)}_{\text{value-added Price}} = \phi_{ik} P_{ik}^{\frac{1}{\phi_{ik}}} \left((1-\phi_{ik}) \prod_{n=\{a,m,s\}} \left(\frac{\gamma_{ikn}}{P_{in}} \right)^{\gamma_{ikn}} \right)^{\frac{1-\phi_{ik}}{\phi_{ik}}}$$

D.2.3 Sectoral Aggregate Prices

In the open economy, the prices after trade costs are

$$P_{ik}(z) = d_{ijk} \frac{V_{ik}(z)}{A_{ik}(z)}$$

Given that productivity follows Frechet distribution, the distribution of prices at the goods level is

$$G_{ijk}(P(z)) = Pr[P_{ijk}(z) \leq P] = 1 - e^{-(T^{-\phi} z)^{-\theta}} = 1 - e^{-\left(T_{ik}^{-\phi_{ik}} \left\{ \frac{V_{ik} d_{ijk}}{P} \right\} \right)^{-\theta}}$$

Now, one chooses to buy from the cheapest source, so the price of good z in the country i is

$$P_{ik}(z) = min_j \{ P_{ijk}(z) \}$$

and that follows the distribution

$$G_{ik}(P) = 1 - \prod_i \Big(1 - G_{ijk}(P(z)) \Big) = 1 - e^{-\left(\sum_i T_{ik}^{-\phi_{ik}} \left\{ \frac{V_{ik} d_{ijk}}{P} \right\} \right)^{-\theta}} = 1 - e^{-\Phi_{ik} \frac{1}{P}^{-\theta}}$$

where $\Phi_{ik} \equiv \sum_{j=1,2,3} \left\{ T_{ik}^{-\phi_{ik}} V_{ik} d_{ijk} \right\}^{-\theta}$.

The aggregate prices corresponding to the sectoral composite good is CES aggregate:

$$P_{ik} = \left(\int_0^1 (P_{ik}(z))^{1-\eta} \right)^{\frac{1}{1-\eta}}$$

Therefore, Aggregate sectoral prices will be

$$P_{ik} = \mathbf{E} \left[\left(\int_0^1 (e^{-\Phi_{ik} z^{-\theta}})^{1-\eta} \right)^{\frac{1}{1-\eta}} \right]$$

$$P_{ik} = \left(\Phi_{ik}^{-\frac{1-\eta}{\theta}} \Gamma \Big[1 - \frac{\eta - 1}{\theta} \Big] \right)^{\frac{1}{1-\eta}} = \Phi_{ik}^{-\frac{1}{\theta}} \underbrace{\left(\Gamma \Big[1 - \frac{\eta - 1}{\theta} \Big] \right)^{\frac{1}{1-\eta}}}_{\xi} = \xi \Phi_{ik}^{-\frac{1}{\theta}}$$

D.2.4 Trade Share

$$\pi_{jik} = \frac{(T_{ik}^{-\phi_{ik}} V_{ik} d_{jik})^{-\theta}}{\Phi_{jk}} = \frac{(T_{ik}^{-\phi_{ik}} V_{ik} d_{jik})^{-\theta}}{\sum_{i=1,2,3} (T_{ik}^{-\phi_{ik}} V_{ik} d_{jik})^{-\theta}}$$

D.2.5 Average Sectoral Productivity

The price in sector k can be written as;

$$P_{ik} = \xi \Phi_{ik}^{-1/\theta} = \xi \left(\sum_{j=1,2,3} (T_{ik}^{-\phi_{ik}} V_{ik} d_{jik})^{-\theta} \right)^{-1/\theta}$$

Multiplying and dividing by $(T_{ik}^{-\phi_{ik}} V_{ik} d_{iik})$;

$$P_{ik} = \xi (T_{ik}^{-\phi_{ik}} V_{ik} \underbrace{d_{iik}}_{=1})^{-\theta} \left(\underbrace{\frac{\sum_{j=1,2,3} (T_{ik}^{-\phi_{ik}} V_{ik} d_{jik})^{-\theta}}{(T_{ik}^{-\phi_{ik}} V_{ik} d_{iik})}}_{1/\pi_{iik}} \right)^{-1/\theta} = \xi (T_{ik}^{-\phi_{ik}} V_{ik}) \left(1/\pi_{iik}\right)^{\frac{-1}{\theta}}$$

$$A_{ik} = \frac{V_{ik}}{P_{ik}} = \xi^{-1} T_{ik}^{\phi_{ik}} \pi_{iik}^{-1/\theta}$$

D.2.6 Trade Cost

Given Ts and Prices, we can pin down the trade cost using the trade shares equation.

$$\frac{\pi_{jik}}{\pi_{jjk}} = \frac{T_{ik} (v_{ik} d_{jik})^{-\theta} / \Phi_{jk}}{T_{jk} (v_{jk} d_{jjk})^{-\theta} / \Phi_{jk}}$$

$$d_{jik} = \left(\frac{\pi_{jik}}{\pi_{jjk}} \right)^{-1/\theta} \left(\frac{T_{jk}}{T_{ik}} \right)^{-1/\theta} \frac{v_{jk}}{v_{ik}}$$

$$d_{jik} = \left(\frac{\pi_{jik}}{\pi_{jjk}} \right)^{-1/\theta} \left(\frac{T_{jk}}{T_{ik}} \right)^{-1/\theta} \left(\frac{A_{jk}}{A_{ik}} \right) \frac{p_{jk}}{p_{ik}}$$

Using the Mapping of measured productivity with fundamental productivity;

$$d_{jik} = \left(\frac{\pi_{jik}}{\pi_{jjk}} \right)^{-1/\theta} \left(\frac{T_{jk}}{T_{ik}} \right)^{-1/\theta} \left(\left(\frac{T_{jk}}{T_{ik}} \right)^{1/\theta} \left(\frac{\pi_{jjk}}{\pi_{iik}} \right)^{-1/\theta} \right) \frac{p_{jk}}{p_{ik}}$$

$$d_{jik} = \left(\frac{\pi_{jik}}{\pi_{iik}} \right)^{-1/\theta} \frac{p_{jk}}{p_{ik}}$$

E Additional Figures

E.1 Calibrated Processes

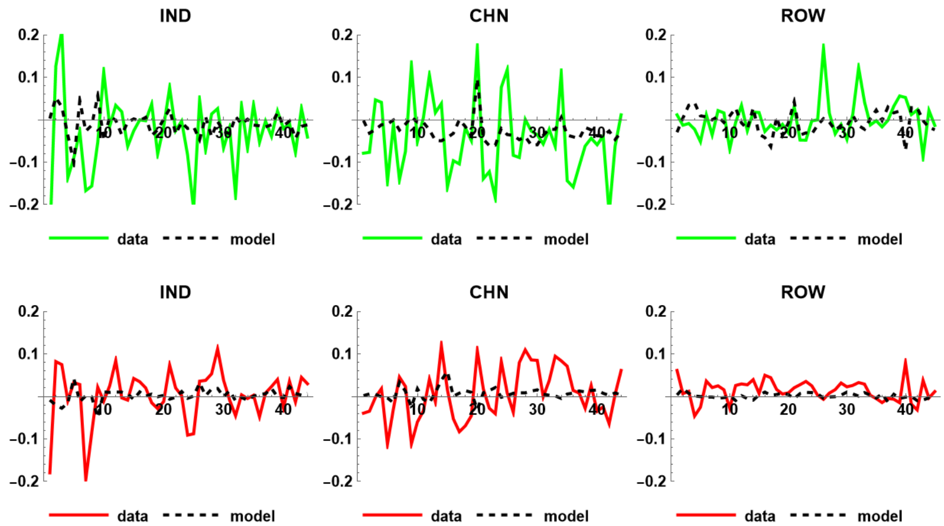

Figure 12: *The fit of the growth rate of sectoral consumption expenditures (y-axis) vis-a-vis that of manufacturing over the year(x-axis). The dotted black line follows the long-term trend of the colorful lines of data; however ignores the short-term cyclicity.*

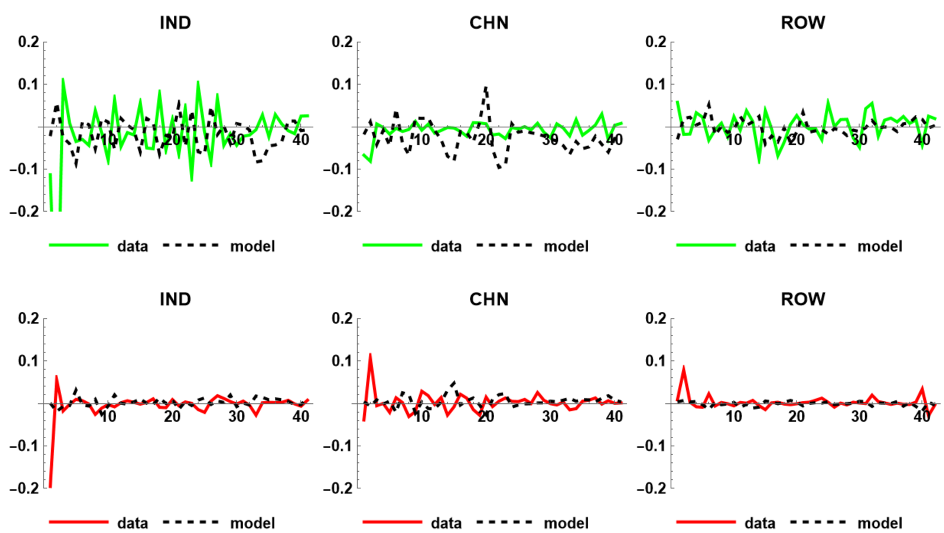

Figure 13: *The fit of the growth rate of sectoral Investment expenditures (y-axis) vis-a-vis that of manufacturing over the year(x-axis).*

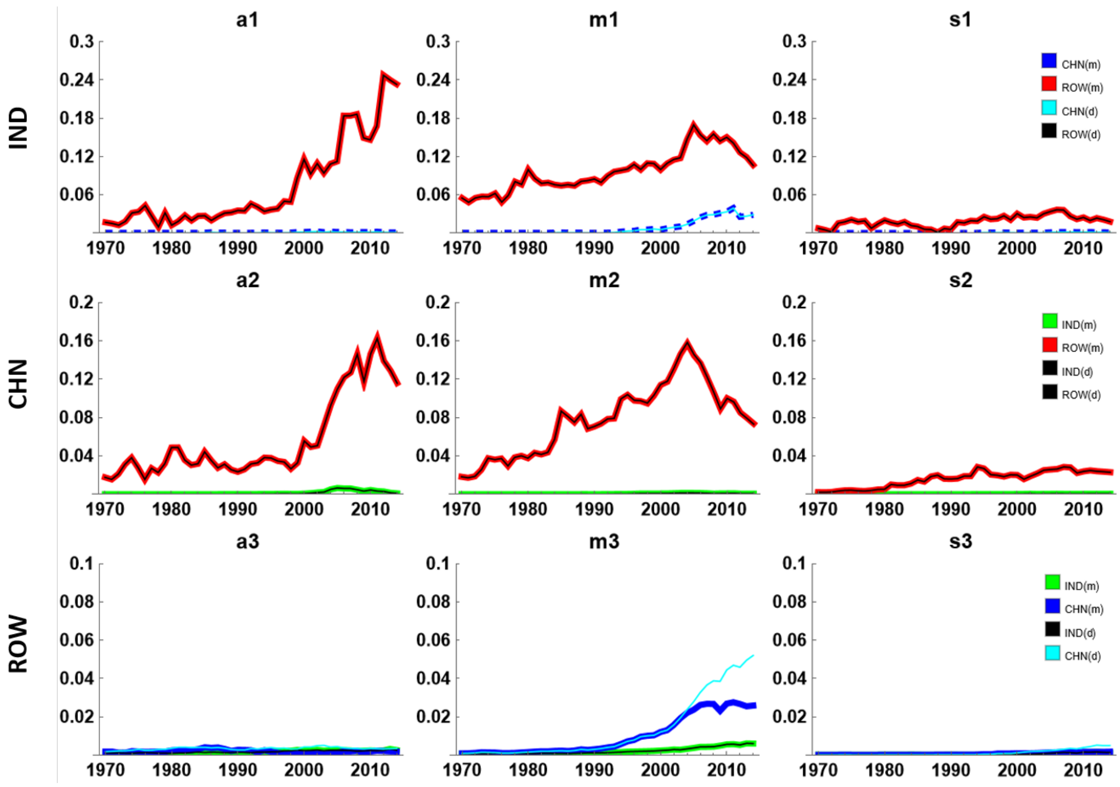

Figure 14: *Fitting the data on each sector and country's Sectoral Bilateral Trade shares.*

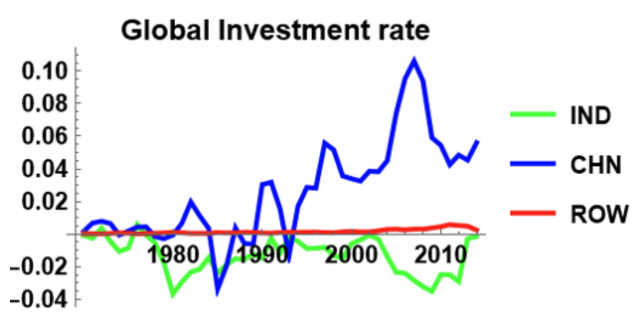

Figure 15: *CHN has a trade surplus, whereas IND and ROW run a deficit.*

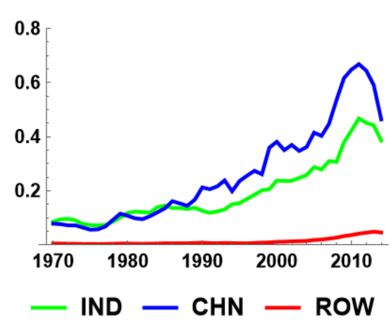

Figure 16: *IND's trade openness index has been on an averge 10-12% lower than that of China after 1980.*