Structural Change in the Global Economy*

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Abstract

In the last few decades, advanced countries have witnessed a significant decline in their manufacturing sectors along with emerging economies being integrated into the global economy. Even had such a globalization not been for, the fall in manufacturing might have been inevitable because of structural change, a stylized fact of economic growth that economies shift from agriculture to manufacturing and then to service. What role does structural change play in determining the impact of globalization? To address the question, we developed a quantitative dynamic general equilibrium model of trade with capital accumulation *á la* Eaton et al. (2016) and Caliendo and Parro (2015). Our model features nonhomothetic CES preferences developed by Comin et al. (2021), allowing consumers to present varying income elasticities of demand across sectors. We bring the model to the data for the world economy, encompassing three sectors (agriculture, manufacturing, and service) and 24 countries. We calibrate the model's fundamentals including trade costs and productivity and solve the model for the transition path. By applying counterfactual trade costs for different sectors, productivity levels, and preferences to the model, we discuss how these factors collectively shape the structural change and its interaction with international trade in advanced countries. Specifically, we show that international trade has heterogeneous impacts on the declining manuacturing across countries, providing new insights into the impacts of globalization on the advanced economies.

JEL Classification: F1 (Trade), O1 (Economic Development)

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1 Introduction

One of the most heated discussions in the last few decades in academic and policy arenas is the significant impacts of globalization on developed countries. The 1990s witnessed the United States (US) lowering trade barriers against Mexico under the North American Free Trade Agreement (NAFTA). In the 2000s, particularly noteworthy are China's accession to the World Trade Organization (WTO) in 2001 and the eastward enlargement of the European Union (EU). A number of studies find adverse effects of these events on industries in developed economies, in particular, their manufacturing employment. Looking at the impacts of China's growing trade, for example, Acemoglu et al. (2016) report 2.0 to 2.4 million US manufacturing workers losing their jobs due to Chinese import competition over 1999 to 2011.[1] Figure 1 (a) shows the evolution of manufacturing value-added share in GDP of selected countries over the past five decades, from 1965 to 2014. The sharp drop in US manufacturing is evident after the 2000s, and one may argue this can be largely due to the "China shock."

From the viewpoint of long-term economic development, however, the manufacturing sector in developed countries is bound to shrink even if the impacts of international trade is not taken into account. As the nation's income grows, it reallocates resources from agriculture, manufacturing, and then to service in a process known as structural change (Kuznets, 1973; Herrendorf et al., 2014). Figure 1 illustrates this point: manufacturing value-added share in the US and Germany started to decline decline in the 1960s (Figure 1 (a)), whereas service value-added share steadily increased over time (Figure 1 (b)). Japan and China exhibit a similar pattern with a time lag.

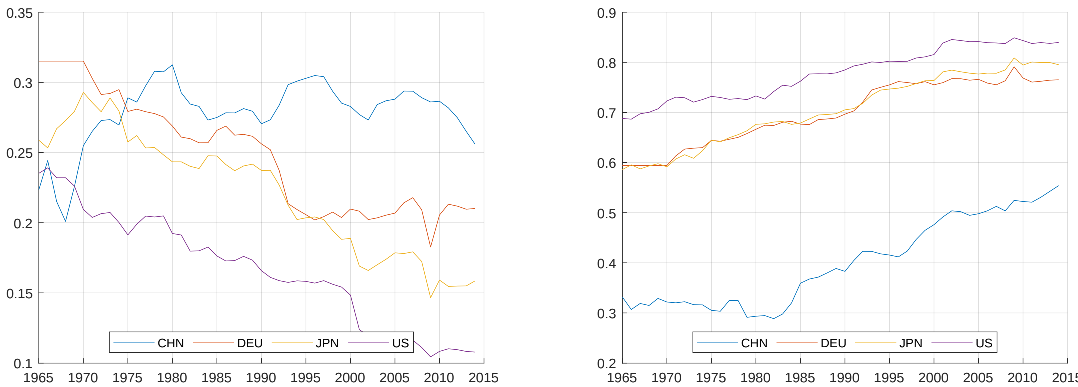
These different views on declining manufacturing in developed countries lead to a number of important questions: What is the role of structural change in determining the impact of growing international trade on resource allocation between sectors? Specifically, to what extent can changes in manufacturing value-added share be attributed to trade and structural change? Whether structural change strengthens or weakens the trade impact in different countries, and if so, how much? How does structural change affect the trade impact on the redistribution of labor and capital income in each sector?

To answer these questions, we propose a unified framework of trade, structural change, and endogenous capital accumulation. We model trade based on the Ricardian comparative advantage *à la* Eaton and Kortum (2002); Caliendo and Parro (2015) and also highlight two prominent drivers of structural change pointed out in the literature: one focusing on the supply side and the other on the demand side (see for Acemoglu, 2008, Ch.20 a survey).

[1] See also Autor et al. (2013); Acemoglu et al. (2016); Pierce and Schott (2016). The adverse effects of rising Chinese imports are observed in other developed countries, including Canada (Albouy et al., 2019), Denmark (Utar, 2018), France (Malgouyres, 2017), and Germany (Dauth et al., 2014). See also Autor et al. (2016) for a comprehensive review. We note, however, that not all studies find negative effects of rising Chinese imports on developed countries. Taniguchi (2019), for example, finds a positive effect of the China shock in Japan due to the complementary role of imported intermediate inputs.

Figure 1: Value Added Share in GDP

(a) Manufacturing (b) Service



Notes: The data is from the WIOD database. See Section 4 for details.

The supply-side mechanism, also known as the Baumol effect, refers to the substitution of production due to changes in relative prices associated with sector-biased technological change (Baumol, 1967; Ngai and Pissarides, 2007). We capture this by allowing sector-biased technological change and changes in the composition of sectoral inputs in production and investment as in García-Santana et al. (2021); Herrendorf et al. (2021). On the other hand, the demand-side mechanism emphasizes the non-homothetic preference such that, as income grows, consumers shift their expenditure from the less-income-elastic goods such as foods to the more-income-elastic goods such as services (Kongsamut et al., 2001). Our model employs the non-homothetic CES preference as in Hanoch (1975); Matsuyama (2019); Comin et al. (2021).[2] Finally, we model forward-looking decisions on capital investment as in Eaton et al. (2016); Ravikumar et al. (2019).

We calibrate our model using the data for 24 countries over half the century, from 1965 to 2014. Our quantification strategy calibrates the model's fundamentals, such as sectoral productivity, trade costs, which allows us to solve the transition paths of the economy in terms of *level*, not in *relative change* known as hat-algebra method Caliendo and Parro (2015); Caliendo et al. (2019). We then conduct a counterfactual analysis to examine the role of international trade in shaping the industrial structure of advanced economies.

Specifically, we ask what the sectoral composition of the economy would look like if the trade costs were as high as at the 1965 level. First of all, our results show that the role of trade in shaping sectoral composition has become more important over time in many countries and

[2] Unlike more standard ones such as the Stone-Geary, the non-homothetic CES preference shows non-vanishing non-unitary income elasticities as income grows, which is consistent with the finding of Comin et al. (2021), while maintaining analytical tractability as much as possible.

particularly so since around the 1990s. In Germany, for instance, the counterfactual changes in sectoral value-added share remained within a 6% point range before 2000. However, these changes have notably increased since then, surpassing even 20% point in some years. This reflects significant reductions in trade costs in the last three decades.

Another interesting result is that international trade has heterogeneous impacts on the manufacturing share across countries. Specifically, we find that international trade substantially contributes to the decline in US manufacturing, while its impacts in Germany and Japan are the opposite. Due to the reduction in trade costs from the 1965 to the current level, the manufacturing value-added share in the US on average decreases by 12.1% point in 2001 to 2007, while the share in Germany and Japan on average increases respectively by 0.7% point and 8.3% point during the same period. This can be explained by the interactions of comparative advantage and forces of structural change. The US in the 2000s saw greater trade costs reduction in service than in manufacturing and had a comparative *dis*advantage in manufacturing sector due to its relatively low productivity to service.Lower trade costs allow the US to export more services and shift labor and capital to the comparative-advantage sector. This sectoral reallocation is further strengthened by the Baumol effect; i.e., importing cheaper manufacturing goods from abroad allows the US consumers spend less on manufacturing and more on services, as the price elasticity of demand for each good is sufficiently low.

Our study is positioned in the recent literature on quantitative models of structural change embedding international trade (see Alessandria et al., 2023 for a survey). Those studies show a number of new insights such as the decomposition of different mechanisms for declining manufacturing share (Święcki, 2017; Smitkova, 2023), a systematic relationship between countries' intermediate-input intensities and their level of development (Sposi, 2019), and the negative effect of structural change on trade (Lewis et al., 2022). In modeling international trade, these studies follow static models of Eaton and Kortum (2002) and Caliendo and Parro (2015).

Unlike those studies, we propose a dynamic model with endogenous capital accumulation *à la* Eaton et al. (2016) and Ravikumar et al. (2019), which allows us to explain the evolution of sectoral production and production as endogenous outcomes rather than calibration results. This is far from a trivial extension since recent studies in the closed-economy context emphasize the role of investment (e.g., Herrendorf et al., 2014, Sec. 6.3.3) in shaping the industrial structure of the economy. Moreover, our model can speak to the dynamics of trade balance and how this interacts with structural change (Kehoe et al., 2018).

Our paper is most closely related to Sposi et al. (2021), which develops and applies the dynamic model of international trade to study structural change.[3] Despite the similarity in

[3]Another closely related study is Święcki (2017) examining to what extent each elements of the model contributes to changes in sectoral composition. He finds that the most important element is the sector-biased productivity. We depart from his static model with non-tradable services by allowing for endogenous capital accumulation and tradable services. His finding might be due to his calibration based on the model without

the analytical framework, we have a different set of questions. Sposi et al. (2021) focuse on the recent empirical finding of "premature deindustrialization," which conceptualizes that developing countries today experience the transition from manufacturing to service much earlier than those several decades ago (Rodrik, 2016). Furthermore, they also show new evidence that the cross-country dispersion of manufacturing share has increased over time. Our paper contrasts with their study by emphasizing more country- and region-specific episodes of globalization. While the current manuscript only presents a counterfactual exercise with changing the trade costs universally, we plan to focus on the specific trade shock episolodes, such as WTO accession of China and the EU enlargement, and their impacts on the evolution of the industrial structure of the advanced economies. Furthermore, we to evaluate the welfare effects of these episodes by measuring the equivalent variation of trade shocks and provide a novel decomposition into the terms of trade effect and other effects in an analytical form. We then attempt to quantitatively evaluate each effect and investigate if there are systematic relationships between welfare effects and shifts in sectoral expenditure/production.

The remainder of this paper is structured as follows: section 2 presents the model, section 3 discusses qualitative results of the model, section 4 introduces the calibration of the model and solution algorithm, section 5 presents the quantitative results, and section 6 concludes.

2 Model

We consider a dynamic economy in which time is discrete $t = 0, 1, \cdots$. The set of countries is $\mathcal{N} = \{1, 2, \cdots, N\}$. Thus, the cardinality of $\mathcal{N}$ is N. Countries are generically indexed by i or n. There are three sectors: agriculture, manufacturing, and services. Sectors are generically indexed by $j = a, m, s$, where a, m, and s stand for agriculture, manufacturing, and services, respectively. Sectors and industries are synonymous in this paper.

The representative household in country n as of period 0 maximizes the lifetime utility function

$$\sum_{t=0}^{\infty} \beta^t \zeta_{n,t} L_{n,t} \frac{(C_{n,t}/L_{n,t})^{1-\psi}}{1-\psi}, \tag{1}$$

where $\beta \in (0, 1)$ is the discount factor, $\psi > 1$ is the intertemporal elasticity of substitution, $\zeta_{n,t}$ is the demand shifter in country n and period t, and $L_{n,t}$ is the population of country n and period t. The aggregate consumption in country n and period t, $C_{n,t}$, is *implicitly* defined by

$$\sum_{j=a,m,s} (\Omega^j)^{\frac{1}{\sigma}} \left(\frac{C_{n,t}}{L_{n,t}}\right)^{\frac{\epsilon^j(1-\sigma)}{\sigma}} \left(\frac{C^j_{n,t}}{L_{n,t}}\right)^{\frac{\sigma-1}{\sigma}} = 1, \tag{2}$$

capital, because the estimates of sector-biased sectoral productivity potentially include the contribution by capital. We instead model capital explicitly and give more precise estimates of productivities.

where, for $j = a, m, s$, $C^j_{n,t}$ is the composite good of sector j which the representative household in country n and period t consumes, Ω^j is the demand shifter for sector j, ϵ^j is the parameter governing how the period utility changes as the composite good of sector j changes (nonhomotheticity), and σ is the (intratemporal) elasticity of substitution across the sectoral composite goods. The period utility function (2) follows Hanoch (1975) and Comin et al. (2021). Following Eaton and Kortum (2002), we assume that a unit continuum of varieties exists in each sector. For $j = a, m, s$, the composite good of sector j which country n consumes in period t is defined to be

$$C^j_{n,t} = \left[\int_0^1 C^j_{n,t}(z)^{\frac{\eta-1}{\eta}} dz \right]^{\frac{\eta}{\eta-1}},$$

where η is the elasticity of substitution across varieties within sectors.

Solving the intratemporal expenditure minimization problem given $C_{n,t}$, the expenditure of country n in period t is

$$E_{n,t} = L_{n,t} \left[\sum_{j=a,m,s} \Omega^j_{n,t} \left\{ \left(\frac{C_{n,t}}{L_{n,t}} \right)^{\epsilon^j} P^j_{n,t} \right\}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \tag{3}$$

where $P^j_{n,t}$ is the price of the composite good of sector j in country n and period t. Define $P_{n,t}$ by $P_{n,t} = E_{n,t}/C_{n,t}$. Then we have

$$P_{n,t} = \left[\sum_{j=a,m,s} \Omega^j_{n,t} (P^j_{n,t})^{1-\sigma} \left(\frac{C_{n,t}}{L_{n,t}} \right)^{(1-\sigma)(\epsilon^j-1)} \right]^{\frac{1}{1-\sigma}}.$$

The consumption of the composite good of sector j is

$$C^j_{n,t} = L_{n,t} \Omega^j_{n,t} \left(\frac{P^j_{n,t}}{P_{n,t}} \right)^{-\sigma} \left(\frac{C_{n,t}}{L_{n,t}} \right)^{(1-\sigma)\epsilon^j+\sigma}. \tag{4}$$

Let $\omega^j_{n,t}$ be country n's expenditure share on sector j in period t, that is, $\omega^j_{n,t} = E^j_{n,t}/E_{n,t}$, where $E^j_{n,t}$ denotes country n's expenditure on sector j goods (or services) in period t. Then we have

$$\omega^j_{n,t} = \frac{\Omega^j_{n,t} \left\{ \left(\frac{C_{n,t}}{L_{n,t}} \right)^{\epsilon^j} P^j_{n,t} \right\}^{1-\sigma}}{\sum_{h=a,m,s} \Omega^h_{n,t} \left\{ \left(\frac{C_{n,t}}{L_{n,t}} \right)^{\epsilon^h} P^h_{n,t} \right\}^{1-\sigma}},$$

and

$$\frac{\omega_{n,t}^{h}}{\omega_{n,t}^{j}} = \left(\frac{P_{n,t}^{h}}{P_{n,t}^{j}}\right)^{1-\sigma} \left(\frac{C_{n,t}}{L_{n,t}}\right)^{(1-\sigma)(\epsilon_h-\epsilon_j)} \left(\frac{\Omega^{h}}{\Omega^{j}}\right). \tag{5}$$

By definition, $\sum_{j=a,m,s} \omega_{n,t}^{j} = 1$. See Comin et al. (2021) for detailed derivations of (3) and (5).

The representative household in country n is the sole owner of labor and capital there. The budget constraint of country n in period t is

$$E_{n,t} + P_{n,t}^{K} I_{n,t} \leq (1-\phi_{n,t})(r_{n,t}K_{n,t} + w_{n,t}L_{n,t}) + L_{n,t}T_{t}^{P}, \tag{6}$$

where $P_{n,t}^{K}$ is the capital good price index which will be defined later, $I_{n,t}$ is the quantity of investment, $\phi_{n,t}$ is the fraction of the aggregate income accrued to the global portfolio, and T_{t}^{P} is the payment from the global portfolio to each person of country n in period t. Note that $\phi_{n,t}$ is an exogenous parameter such that the equilibrium trade surplus (or deficit) matches with the data counterpart.

Let $K_{n,t}$ be the quantity of capital in country n and period t. Then, capital dynamics are

$$K_{n,t+1} = (1-\delta_{n,t})K_{n,t} + (I_{n,t})^{\lambda}(\delta_{n,t}K_{n,t})^{1-\lambda}, \tag{7}$$

where $\delta_{n,t}$ is the capital depreciation rate in country n and period t and the investment $I_{n,t}$ is a function of $K_{n,t}$ and $K_{n,t+1}$

$$I_{n,t}(K_{n,t}, K_{n,t+1}) \equiv \delta_{n,t}^{1-\frac{1}{\lambda}} \left(\frac{K_{n,t+1}}{K_{n,t}} - (1-\delta_{n,t})\right)^{\frac{1}{\lambda}} K_{n,t}. \tag{8}$$

This formulation captures the stickiness of investment with λ capturing how easy the investment adjustment is. If $\lambda = 1$, the adjustment is fully flexible so that $K_{n,t+1}$ is freely chosen independent of $K_{n,t}$. If $\lambda = 0$, the adjustment is impossible and capital stock remains its past level, $K_{n,t+1} = K_{n,t}$.

The dynamic optimization problem of the representative household in country n and period 0 is

$$\max \ (1),$$

subject to (3), (6), and (7). Solving this problem, we obtain the Euler equation

$$\frac{C_{n,t+1}^{\psi-1} E_{n,t+1}\bar{\epsilon}_{n,t+1}}{C_{n,t}^{\psi-1} E_{n,t}\bar{\epsilon}_{n,t}} = \beta \frac{\zeta_{n,t+1} L_{n,t+1}^{\psi}}{\zeta_{n,t} L_{n,t}^{\psi}} \frac{((1-\delta_{n,t+1})P_{n,t+1}^{K} + (1-\phi_{n,t+1})r_{n,t+1})}{P_{n,t}^{K}}, \tag{9}$$

where

$$\bar{\epsilon}_{n,t} = \sum_{j=a,m,s} \omega_{n,t}^{j} \epsilon^{j}, \tag{10}$$

that is, for country n and period t, $\bar{\epsilon}_{n,t}$ is the weighted sum of $\{\epsilon_j\}_{j=a,m,s}$ with the expenditure shares $\{\omega_{n,t}^{j}\}_{j=a,m,s}$ being the weights.

We have described households' behavior thus far. We move on to producers' behavior. The production function of variety $z \in [0,1]$ of sector j in country n and period t is

$$y_{n,t}^{j}(z) = a_{n,t}^{j}(z) \left(\frac{K_{n,t}^{j}(z)}{\gamma_{n,t}^{j} \alpha_{n,t}^{j}} \right)^{\gamma_{n,t}^{j} \alpha_{n,t}^{j}} \left(\frac{L_{n,t}^{j}(z)}{\gamma_{n,t}^{j}(1-\alpha_{n,t}^{j})} \right)^{\gamma_{n,t}^{j}(1-\alpha_{n,t}^{j})} \left(\frac{M_{n,t}^{j}(z)}{1-\gamma_{n,t}^{j}} \right)^{1-\gamma_{n,t}^{j}}. \tag{11}$$

Here $y_{n,t}^{j}(z)$ is the quantity of output, $a_{n,t}^{j}(z)$ is the productivity which will be expressed as a realization of a random variable, $K_{n,t}^{j}(z)$ is the capital, $L_{n,t}^{j}(z)$ is the labor, $\gamma_{n,t}^{j} \in (0,1)$ is the value-added share, that is, the cost share on production factors (labor and capital), not on intermediate inputs, $\alpha_{n,t}^{j} \in (0,1)$ is the cost share on capital *within production factors*, $M_{n,t}^{j}(z)$ is the CES aggregate of sectoral intermediate goods used for production of variety z, that is,

$$M_{n,t}^{j}(z) = \left(\sum_{h=a,m,s} (\kappa_{n,t}^{j,h})^{\frac{1}{\sigma^j}} (M_{n,t}^{j,h}(z))^{\frac{\sigma^j-1}{\sigma^j}} \right)^{\frac{\sigma^j}{\sigma^j-1}},$$

where $\kappa_{n,t}^{j,h}$ is the shifter for sector j's demand for sector-h goods, $M_{n,t}^{j,h}(z)$ is the input of sector-h good for the production of variety z of sector j, and σ^j is the elasticity of substitution across sectoral goods for the production of sector j goods. In the production of sector-j goods, the cost share on sector-h goods *within intermediate-good costs* is

$$g_{n,t}^{j,h} = \frac{\kappa_{n,t}^{j,h} (P_{n,t}^{h})^{1-\sigma^j}}{\sum_{j"=a,m,s} \kappa_{n,t}^{j,j"} (P_{n,t}^{j"})^{1-\sigma^j}}.$$

The productivity of variety z of sector j in country n and period t, $a_{n,t}^{j}$, follows the Frechét distribution whose the probability distribution function is

$$F_{n,t}^{j}(a) = Pr[a_{n,t}^{j} \leq a] = \exp\left[-\left(\frac{a}{\widetilde{\gamma}^j A_{n,t}^{j}} \right)^{-\theta^j} \right].$$

Here θ^j and $A_{n,t}^{j}$ are the shape parameter and the location parameter of the Frechét distribution, respectively, and $\widetilde{\gamma}^j = [\Gamma((\theta^j + 1 - \eta)/\theta^j)]^{\frac{-1}{1-\eta}}$ with $\Gamma(\cdot)$ being the Gamma function is a normalizing constant. Productivity of varieties is independent within and across sectors, countries, and periods.

Solving the cost minimization problem for the production function (11), the cost for an input bundle is

$$\tilde{c}^j_{n,t} = (r_{n,t})^{\gamma^j_{n,t}\alpha^j_{n,t}}(w_{n,t})^{\gamma^j_{n,t}(1-\alpha^j_{n,t})}(\xi^j_{n,t})^{(1-\gamma^j_{n,t})}, \tag{12}$$

where $\xi^j_{n,t}$ is the CES price index for the composite intermediate good for production of sector-j goods

$$\xi^j_{n,t} = \left(\sum_{h=a,m,s} \kappa^{j,h}_{n,t}(P^h_{n,t})^{1-\sigma^j}\right)^{\frac{1}{1-\sigma^j}}. \tag{13}$$

The price index (or the price of the composite good) of sector j in country n and period t is

$$P^j_{n,t} = \left[\sum_{i\in\mathcal{N}} \left(\frac{\tilde{c}^j_{i,t}d^j_{ni,t}}{A^j_{i,t}}\right)^{-\theta^j}\right]^{-1/\theta^j}, \tag{14}$$

where $d^j_{ni,t}$ is the iceberg trade cost of shipping varieties of sector j from country i to country n in period t.

The production function of capital (investment) goods in country n and period t is

$$y^K_{n,t} = \kappa^K_{n,t}\left(\sum_{j=a,m,s}(\kappa^{K,j}_{n,t})^{\frac{1}{\sigma^K}}(M^{K,j}_{n,t})^{\frac{\sigma^K-1}{\sigma^K}}\right)^{\frac{\sigma^K}{\sigma^K-1}},$$

where $\kappa^K_{n,t}$ is the productivity, $M^{K,j}_{n,t}$ is the sector-j goods used for the production of capital goods, and σ^K is the elasticity of substitution across sectoral intermediate goods for the production of capital goods. Then the cost share on sector-j goods

$$g^{K,j}_{n,t} = \frac{\kappa^{K,j}_{n,t}(P^j_{n,t})^{1-\sigma^K}}{\sum_{h=a,m,s}\kappa^{K,}_{n,t}(P^h_{n,t})^{1-\sigma^K}}.$$

The ideal price index of capital goods is

$$P^K_{n,t} = \frac{1}{\kappa^K_{n,t}}\left(\sum_{j=s,m,s}\kappa^{K,j}_{n,t}(P^j_{n,t})^{1-\sigma^K}\right)^{\frac{1}{1-\sigma^K}}.$$

Let $X^j_{ni,t}$ be country n's spending on sector j goods (or services) from country i in period t. This includes spending for consumption, investment, and intermediate inputs. Summing $X^j_{ni,t}$ across i, let $X^j_{n,t}$ be country n's spending on sector j goods (or services) in period t. Let $\pi^j_{ni,t} = X^j_{ni,t}/X^j_{n,t}$, that is, the share of goods from country i within country n's expenditure on sector j goods in period t. We call $\pi^j_{ni,t}$ as trade shares following the literature of quantitative trade models. Following Eaton and Kortum (2002), we have

$$\pi_{ni,t}^{j} = \frac{(\tilde{c}_{i,t}^{j} d_{ni,t}^{j} / A_{i,t}^{j})^{-\theta^j}}{\sum_{i' \in \mathcal{N}} (\tilde{c}_{i',t}^{j} d_{ni',t}^{j} / A_{i',t}^{j})^{-\theta^j}} = \left(\frac{\tilde{c}_{i,t}^{j} d_{ni,t}^{j}}{A_{i,t}^{j} p_{n,t}^{j}} \right)^{-\theta^j}. \tag{15}$$

Let $Y_{n,t}^{j}$ be the gross production of sector j in country n and period t. It is value, not quantity. We have

$$Y_{n,t}^{j} = \sum_{i \in \mathcal{N}} \pi_{in,t}^{j} X_{i,t}^{j}. \tag{16}$$

Country n's spending on sector-j goods in period t consists of the final consumption, the input for the production of capital goods, and the input for the production of goods and services of various sectors

$$X_{n,t}^{j} = P_{n,t}^{j} C_{n,t}^{j} + g_{n,t}^{K,j} P_{n,t}^{K} I_{n,t} + \sum_{h=a,m,s} (1 - \gamma_{n,t}^{h}) g_{n,t}^{h,j} Y_{n,t}^{h}. \tag{17}$$

Substituting (16) into (17), we obtain a system of linear equations of $\{X_{n,t}^{j}\}_{n \in \mathcal{N}, j=a,m,s}$ given other variables. We see this in the following. For any sector j and period t, define $\vec{X}_t$, π_t^j, and $\vec{Y}_t^j$ by

$$\vec{X}_t^j = \begin{bmatrix} X_{1,t}^{j} \\ \vdots \\ X_{N,t}^{j} \end{bmatrix}, \; \pi_t^j = \begin{bmatrix} \pi_{11,t}^{j}, & \cdots, & \pi_{N1,t}^{j} \\ \vdots & & \vdots \\ \pi_{N1,t}^{j}, & \cdots, & \pi_{NN,t}^{j} \end{bmatrix}, \; \vec{Y}_t^j = \begin{bmatrix} Y_{1,t}^{j} \\ \vdots \\ Y_{N,t}^{j} \end{bmatrix}, \tag{18}$$

respectively. For an arbitrary matrix A, A^T denotes the transpose of A. (16) can be rewritten as

$$\vec{Y}_t^j = (\pi_t^j)^T \vec{X}_t^j.$$

For $j = a, m, s$ (or K) and $h = a, m, s$, define $\vec{P}_t^j$, $\vec{C}_t^j$, $\vec{I}_t$, $\vec{g}_t^{j,h}$, $\vec{\gamma}_t^j$ by

$$\vec{P}_t^j = \begin{bmatrix} P_{1,t}^{j} \\ \vdots \\ P_{N,t}^{j} \end{bmatrix}, \; \vec{C}_t^j = \begin{bmatrix} C_{1,t}^{j} \\ \vdots \\ C_{N,t}^{j} \end{bmatrix}, \; \vec{I}_t = \begin{bmatrix} I_{1,t} \\ \vdots \\ I_{N,t} \end{bmatrix}, \; \vec{g}_t^{j,h} = \begin{bmatrix} g_{1,t}^{j,h} \\ \vdots \\ g_{N,t}^{j,h} \end{bmatrix}, \; \vec{\gamma}_t^j = \begin{bmatrix} \gamma_{1,t}^{j} \\ \vdots \\ \gamma_{N,t}^{j} \end{bmatrix}$$

Let $\circ$ denote the element-by-element (or Hadamard) product. Then for $j = a, m, s$, (17) can be rewritten as

$$\begin{aligned} \vec{X}_t^j &= \vec{P}_t^j \circ \vec{C}_t^j + \vec{g}_t^{K,j} \circ \vec{P}_t^K \circ \vec{I}_t + \sum_{h=a,m,s} \vec{g}_t^{h,j} \circ (1_N - \vec{\gamma}_t^h) \circ \vec{Y}_t^h \\ &= \vec{P}_t^j \circ \vec{C}_t^j + \vec{g}_t^{K,j} \circ \vec{P}_t^K \circ \vec{I}_t + \sum_{h=a,m,s} \vec{g}_t^{h,j} \circ (1_N - \vec{\gamma}_t^h) \circ ((\pi_t^h)^T \vec{X}_t^h), \end{aligned}$$

where 1_N is the n-dimensional vertical vector whose element is one, and the second equality follows from (18). Stacking vectors and matrices across sectors, we define $\vec{X}_t$, $\vec{F}_t$, and $\tilde{\pi}_t$ by

$$\vec{X}_t = \begin{bmatrix} \vec{X}_t^a \\ \vec{X}_t^m \\ \vec{X}_t^s \end{bmatrix}, \ \vec{F}_t = \begin{bmatrix} \vec{P}_t^a \circ \vec{C}_t^a + \vec{g}_t^{K,a} \circ \vec{P}_t^K \circ \vec{I}_t \\ \vec{P}_t^m \circ \vec{C}_t^m + \vec{g}_t^{K,m} \circ \vec{P}_t^K \circ \vec{I}_t \\ \vec{P}_t^s \circ \vec{C}_t^s + \vec{g}_t^{K,s} \circ \vec{P}_t^K \circ \vec{I}_t \end{bmatrix}, \ \tilde{\pi}_t = \begin{bmatrix} \pi_t^a & 0_{N\times N} & 0_{N\times N} \\ 0_{N\times N} & \pi_t^m & 0_{N\times N} \\ 0_{N\times N} & 0_{N\times N} & \pi_t^s \end{bmatrix},$$

where $0_{N\times N}$ is the $N \times N$ matrix whose elements are all zero. For any $j = a, m, s$ and $h = a, m, s$, define Γ_t^j and $G_t^{h,j}$ by

$$\Gamma_t^j = \begin{bmatrix} 1-\gamma_{1,t}^j & 0 & \cdots & 0 \\ 0 & 1-\gamma_{2,t}^j & \cdots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & 1-\gamma_{N,t}^j \end{bmatrix}, \ G_t^{h,j} = \begin{bmatrix} g_{1,t}^{h,j} & 0 & \cdots & 0 \\ 0 & g_{2,t}^{h,j} & \cdots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & g_{N,t}^{h,j} \end{bmatrix}.$$

Then further define G_t and Γ_t by

$$G_t = \begin{bmatrix} G_t^{a,a} & G_t^{m,a} & G_t^{s,a} \\ G_t^{a,m} & G_t^{m,m} & G_t^{s,m} \\ G_t^{a,s} & G_t^{m,s} & G_t^{s,s} \end{bmatrix}, \ \Gamma_t = \begin{bmatrix} \Gamma_t^a & 0 & 0 \\ 0 & \Gamma_t^m & 0 \\ 0 & 0 & \Gamma_t^s \end{bmatrix}.$$

Note that $\vec{X}_t$ and $\vec{F}_t$ are $3N$ vectors, and $\tilde{\pi}_t$ is a $3N \times 3N$ matrix. F in $\vec{F}_t$ stands for final absorption. Note that the transpose of $\tilde{\pi}_t$, $(\tilde{\pi}_t)^T$, is

$$(\tilde{\pi}_t)^T = \begin{bmatrix} (\pi_t^a)^T & 0_{N\times N} & 0_{N\times N} \\ 0_{N\times N} & (\pi_t^m)^T & 0_{N\times N} \\ 0_{N\times N} & 0_{N\times N} & (\pi_t^s)^T \end{bmatrix}.$$

Then (17) is expressed as

$$\vec{X}_t = \vec{F}_t + G_t \Gamma_t (\tilde{\pi}_t)^T \vec{X}_t.$$

Let I_{3N} denote the $3N \times 3N$ unit matrix. Then we have

$$(I_{3N} - G_t \Gamma_t (\tilde{\pi}_t)^T) \vec{X}_t = \vec{F}_t.$$

If $I_{3N} - G_t \Gamma_t (\tilde{\pi}_t)^T$ is a regular matrix, $\vec{X}_t$ is solved as

$$\vec{X}_t = (I_{3N} - G_t \Gamma_t (\tilde{\pi}_t)^T)^{-1} \vec{F}_t. \tag{19}$$

In country n and period t, the aggregate capital income must be equal to the aggregate capital cost

$$r_{n,t}K_{n,t} = \sum_{j=a,m,s} \gamma_{n,t}^j \alpha_{n,t}^j Y_{n,t}^j. \tag{20}$$

Similarly, the aggregate labor income must be equal to the aggregate labor cost

$$w_{n,t}L_{n,t} = \sum_{j=a,m,s} \gamma_{n,t}^j (1-\alpha_{n,t}^j) Y_{n,t}^j. \tag{21}$$

We move on to the budget balance of the global portfolio. The trade surplus is equal to the net payment to the global portfolio

$$\underbrace{\sum_{a,m,s} \gamma_{n,t}^j Y_{n,t}^j - (E_{n,t} + P_{n,t}^K I_{n,t}^K)}_{\text{trade surplus}} = \phi_{n,t}(r_{n,t}K_{n,t} + w_{n,t}L_{n,t}) - L_{n,t}T_t^P. \tag{22}$$

The sum of the net payments from all countries to the global portfolio must be zero

$$\sum_{n=1}^{N} \left\{ \phi_{n,t}(r_{n,t}K_{n,t} + w_{n,t}L_{n,t}) - L_{n,t}T_t^P \right\} = 0.$$

Solving this for T_t^P, we have

$$T_t^P = \frac{\sum_{n=1}^{N} \phi_{n,t}(r_{n,t}K_{n,t} + w_{n,t}L_{n,t})}{\sum_{n=1}^{N} L_{n,t}}. \tag{23}$$

Equilibrium. Given the capital stocks in the initial period $\{K_{n,0}\}_{n\in\mathcal{N}}$, an equilibrium is a tuple of $\{w_{n,t}\}_{n\in\mathcal{N},t=0,\cdots,\infty}$, $\{r_{n,t}\}_{n\in\mathcal{N},t=0,\cdots,\infty}$, $\{E_{n,t}\}_{n\in\mathcal{N},t=0,\cdots,\infty}$, $\{\tilde{c}_{n,t}^j\}_{n\in\mathcal{N},t=0,\cdots,\infty,j=a,m,s}$, $\{P_{n,t}^j\}_{n\in\mathcal{N},t=0,\cdots,\infty,j=a,m,s}$, $\{\pi_{ni,t}^j\}_{(n,i)\in\mathcal{N}\times\mathcal{N},t=0,\cdots,\infty,j=a,m,s}$, $\{Y_{n,t}\}_{n\in\mathcal{N},t=0,\cdots,\infty}$, $\{X_{n,t}^j\}_{n\in\mathcal{N},t=0,\cdots,\infty,j=a,m,s}$, $\{\bar{\epsilon}_{n,t}\}_{n\in\mathcal{N},t=0,\cdots,\infty}$, $\{\omega_{n,t}^j\}_{n\in\mathcal{N},t=0,\cdots,\infty,j=a,m,s}$, $\{C_{n,t}\}_{n\in\mathcal{N},t=0,\cdots,\infty}$, $\{K_{n,t}\}_{n\in\mathcal{N},t=1,\cdots,\infty}$, $\{I_{n,t}\}_{n\in\mathcal{N},t=0,\cdots,\infty}$, $\{T_t^P\}_{t=0,\cdots,\infty}$ satisfying a system of equations (3), (5), (6), (7), (9), (10), (12), (14), (15), (16), (19) (or (17)), (21), (20), (23).

We compute transition paths, that is, equilibria converging to steady states. For this purpose, we define steady states of this model.

Steady state. A steady state is an equilibrium in which variables are time-invariant. Specifically, a steady state is a tuple of $\{w_n\}_{n\in\mathcal{N}}$, $\{r_n\}_{n\in\mathcal{N}}$, $\{E_n\}_{n\in\mathcal{N}}$, $\{\tilde{c}_n^j\}_{n\in\mathcal{N},j=a,m,s}$, $\{P_n^j\}_{n\in\mathcal{N},j=a,m,s}$, $\{\pi_{ni}^j\}_{(n,i)\in\mathcal{N}\times\mathcal{N},j=a,m,s}$, $\{Y_n\}_{n\in\mathcal{N}}$, $\{X_n^j\}_{n\in\mathcal{N},j=a,m,s}$, $\{\omega_n^j\}_{n\in\mathcal{N},j=a,m,s}$, $\{C_n\}_{n\in\mathcal{N}}$, $\{K_n\}_{n\in\mathcal{N}}$ satisfying a system of equations (21), (3), (12), (14), (15), (16), (19), (5),

$$r_nK_n = \frac{\alpha}{1-\alpha} w_nL_n,$$

$$r_n = \frac{1-\beta(1-\delta)}{\beta(1-\phi_n)} P_n^K,$$

and

$$E_n = (1-\phi_n)(r_n K_n + w_n L_n) + L_n T^P - \delta P_n^K K_n,$$

dropping time subscripts t from all the equations.

3 Qualitative Results

Before examining quantitative implications, we qualitatively show how different mechanisms shape the reallication of economic activities across sectors, in particular, changes in sectoral expenditure share and sectoral value-added share. We also provide an analytical formula for evaluating welfare, based on the concept of equivalent variation.

3.1 Mechanisms for Structural Change

3.1.1 Sectoral Expenditure Share

The best consumption measure of structural change is arguably the sectoral expenditure share, $\omega_{n,t}^j = E_{n,t}^j / E_{n,t} = P_{n,t}^j C_{n,t}^j / E_{n,t}$. From consumers' optimal decisions given by (3) and (5), we obtain the following expression for the logarithm changes in $\omega_{n,t}^j$:

$$d \ln \omega_{n,t}^j = \underbrace{(1-\sigma)}_{>0} \Big[\underbrace{(1-\omega_{n,t}^j) d \ln P_{n,t}^j - \sum_{h \neq j} \omega_{n,t}^h d \ln P_{n,t}^h}_{\text{Supply-side channel}} + \underbrace{\left(\epsilon^j - \bar{\epsilon}\right) d \ln \left(\frac{C_{n,t}}{L_{n,t}} \right)}_{\text{Demand-side channel}} \Big],$$

where $\bar{\epsilon} \equiv \sum_{h=a,m,s} \omega_{n,t}^h \epsilon^h$ is the budget-share weighted average of ϵ^h and we assume for simplicity no changes in the demand shifters, $d \ln \Omega_{n,t}^j = 0$. This neatly summarizes the two fundamental mechanisms for structural change at work. To see the supply-side channel captures in the first two terms in the big bracket, suppose the price of sectoral good j falls due to, e.g., increasing sectoral productivity. Given σ being less than unity, this leads to a fall in expenditure on the good. The demand-side channel captured by the third term shows that as per-capita consumption $(C_{n,t}/L_{n,t})$ grows, people spend more on good j if the good has a higher (or lower) ϵ^j than the average $\bar{\epsilon}$, or equivalently an expenditure elasticity higher (or lower) than one.[4] This explains shifts in expenditure from less income-elastic agricultural

[4]The expenditure elasticity of good j is given by

$$\frac{\partial \ln C_{n,t}^j}{\partial \ln E_{n,t}} = \eta + (1-\eta) \frac{\epsilon^j}{\bar{\epsilon}},$$

Given η being greater than one. the expenditure elasticity is higher (or lower) than one if $\epsilon^j > \bar{\epsilon}$ (or $\epsilon^j < \bar{\epsilon}$).

goods to more income-elastic goods such as manufacturing products and luxurious service. Although not explicit here, international trade plays an important role in determining $\omega^j_{n,t}$ through its effect on goods prices, factor prices, and income.

3.1.2 Sectoral Value-Added Share

On the production measure of structural change, any models of structural change have to account for sectoral value-added share defined by

$$\frac{VA^j_{n,t}}{VA_{n,t}} = \frac{r_{n,t}K^j_{n,t} + w_{n,t}L^j_{n,t}}{\sum_{h=a,m,s} r_{n,t}K_{n,t} + w_{n,t}L_{n,t}} = \frac{\gamma^j_{n,t}Y^j_{n,t}}{\sum_{h=a,m,s}\gamma^h_{n,t}Y^h_{n,t}},$$

for $j = a, m, s$. Its logarithm change is given by

$$d\ln\left(\frac{VA^j_{n,t}}{VA_{n,t}}\right) = \left(1 - \frac{VA^j_{n,t}}{VA_{n,t}}\right) d\ln\left(\gamma^j_{n,t}Y^j_{n,t}\right) - \sum_{h\neq j}\frac{VA^h_{n,t}}{VA_{n,t}} d\ln\left(\gamma^h_{n,t}Y^h_{n,t}\right).$$

The share of sector j's value-added naturally increases as capital and labor are more important in producing good j, $d\ln\gamma^j_{n,t} > 0$, or gross production of j increases, $d\ln Y^j_{n,t} > 0$, while it decreases as value added in the other sectors grows, $d\ln(\gamma^h_{n,t}Y^h_{n,t}) > 0$ for $h \neq j$.

To see the sectoral gross production $Y^j_{n,t}$ further, we solve the sectoral goods market clearing condition (18) for $Y^j_{n,t}$ to obtain

$$Y^j_{n,t} = \sum_{h=a,m,s} \lambda^{jh}_{n,t}(P^h_{n,t}C^h_{n,t} + g^{Kh}_{n,t}P^K_{n,t}I_{n,t}),$$

where $\lambda^{jh}_{n,t}$ is a coefficient of the Leontief inverse matrix and shows the amount of sector j's gross production induced by a unit increase in sector h's absorption. The logarithmic change of $Y^j_{n,t}$ can be decomposed into changes in the input-output linkage, final consumption, and investment:

$$d\ln Y^j_{n,t} = \underbrace{\sum_h y^h_{n,t} d\ln\lambda^{jh}_{n,t}}_{\text{Sectoral linkages}} + \underbrace{\sum_h con^h_{n,t}\times y^h_{n,t} d\ln\left(P^h_{n,t}C^h_{n,t}\right)}_{\text{Final consumption}} + \underbrace{\sum_h inv^h_{n,t}\times y^h_{n,t} d\ln\left(g^{Kh}_{n,t}P^K_{n,t}I_{n,t}\right)}_{\text{Investment}},$$

where $y^j_{n,t} = Y^j_{n,t}/\sum_h Y^h_{n,t}$ is the gross production share of sector j and $con^j_{n,t}$ and $inv^j_{n,t}$ are respectively the share of consumption and that of investment in absorption in sector j:

$$con^j_{n,t} \equiv \frac{P^j_{n,t}C^j_{n,t}}{P^j_{n,t}C^j_{n,t} + g^{Kj}_{n,t}P^K_{n,t}I_{n,t}}, \qquad inv^j_{n,t} \equiv 1 - con^j_{n,t}.$$

As in the sectoral expenditure share, preference parameters governing structural change, σ

and ϵ^j, directly affect the change in final consumption:

$$d\ln\omega_{n,t}^j = \underbrace{(1-\sigma)}_{>0}\Bigg[\underbrace{\left(1+\frac{\sigma\omega_{n,t}^h}{1-\sigma}\right)d\ln P_{n,t}^j - \sum_{h\neq j}\frac{\sigma\omega_{n,t}^h}{1-\sigma}d\ln P_{n,t}^h}_{\text{Supply-side channel}} + \underbrace{\left(\epsilon^j + \frac{\sigma\bar{\epsilon}}{1-\sigma}\right)d\ln\left(\frac{C_{n,t}}{L_{n,t}}\right)}_{\text{Demand-side channel}}\Bigg] + d\ln L_n.$$

The value-added share of sector j decreases if the price of good j falls and the prices of other goods rise. It increases as the per-capita consumption rises, and does so more if the good has a higher ϵ^j, or equivalently a higher expenditure elasticity. Changes in prices and the per-capita consumption are of course shaped by not just own country but also the other countries through international trade.

3.2 Welfare Evaluation

3.2.1 Equivalent Valuation

Consider a shock changing the steady-state values of prices $\vec{P}_n$ and utility level U_n. To evaluate welfare impacts of the shock on non-homothetic agents, we cannot rely on the real wage as a measure of welfare because unlike CES preferences the indirect utility function under non-homothetic CES preferences does not coincide with the real wage. We instead rely on the equivalent variation (EV) as in Lewis et al. (2022). Letting x^* be the new steady-state value after the shock, we can write it as $x^* = x + dx$, where dx is a small change in x caused by the shock. The expenditure under post-shock prices is $E_n(\vec{P}_n^*, U_n^*)$. EV is calculated as

$$EV_n = E_n(\vec{P}_n, U_n^*) - E_n(\vec{P}_n, U_n),$$

which states that if consumers get EV_n under pre-shock prices they achieve the same utility level U_n^* as the one they would under post-shock prices.

Using EV_n, the change in the expenditure function can be written as

$$\begin{aligned}
dE_n(\vec{P}_n, U_n) &= E_n(\vec{P}_n^*, U_n^*) - E_n(\vec{P}_n, U_n) \\
&= \underbrace{E_n(\vec{P}_n U_n^*) - E_n(\vec{P}_n, U_n)}_{EV_n} + E_n(\vec{P}_n^*, U_n^*) - E_n(\vec{P}_n U_n^*) \\
&\simeq EV_n + \left[E_n(\vec{P}_n, U_n^*) + \sum_{j=a,m,s} dP_n^j \frac{\partial E_n(\vec{P}_n, U_n^*)}{\partial P_n^j}\right] - E_n(\vec{P}_n U_n^*) \\
&= EV_n + \sum_{j=a,m,s} C_n^j(\vec{P}_n, U_n^*) dP_n^j \\
&= EV_n + \sum_{j=a,m,s} P_n^j C_n^j(\vec{P}_n, U_n) \cdot \frac{C_n^j(\vec{P}_n, U_n^*)}{C_n^j(\vec{P}_n, U_n)} \frac{dP_n^j}{P_n^j},
\end{aligned}$$

where we use a Taylor approximation from the second to the third line and a Shephard's lemma from the third to the fourth line.

Further inspections reveal

$$
\begin{aligned}
\frac{EV_n}{E_n(\vec{P}_n, U_n)} &= d\ln E_n(\vec{P}_n, U_n) - \sum_{j=a,m,s} \omega_n^j(\vec{P}_n, U_n) \cdot \frac{C_n^j(\vec{P}_n, U_n^*)}{C_n^j(\vec{P}_n, U_n)} d\ln P_n^j \\
&\simeq d\ln E_n(\vec{P}_n, U_n) - \sum_{j=a,m,s} \omega_n^j(\vec{P}_n, U_n) d\ln P_n^j, \qquad (24)
\end{aligned}
$$

which captures how much percentage of the expenditure should increase in order for consumers to achieve the same post-shock utility level under current prices. Compensation to consumers increases as the shock increases expenditure (1st term) and decreases prices (2nd term). The second term was simplified as follows:

$$
\begin{aligned}
\frac{C_n^j(\vec{P}_n, U_n^*)}{C_n^j(\vec{P}_n, U_n)} &\simeq \frac{1}{C_n^j(\vec{P}_n, U_n)} \left[C_n^j(\vec{P}_n, U_n) + \sum_{h=a,m,s} dP_n^h \frac{\partial C_n^j(\vec{P}_n, U_n)}{\partial P_n^h} \right] \\
&= \frac{1}{C_n^j(\vec{P}_n, U_n)} \left[C_n^j(\vec{P}_n, U_n) + dP_n^j \frac{\partial C_n^j(\vec{P}_n, U_n)}{\partial P_n^j} \right] \\
&= 1 + \frac{\partial C_n^j(\vec{P}_n, U_n) / C_n^j(\vec{P}_n, U_n)}{\partial P_n^j / P_n^j} \frac{dP_n^j}{P_n^j} \\
&= 1 - \sigma d\ln P_n^j.
\end{aligned}
$$

In deriving this, we assume $dP_n^h \partial C_n^j / \partial P_n^j = 0$ for $h \neq j$ and use the fact that the sectoral demand elasticity is σ (see (4)). This leads to

$$
\begin{aligned}
\sum_{j=a,m,s} \omega_n^j(\vec{P}_n, U_n) \cdot \frac{C_n^j(\vec{P}_n, U_n^*)}{C_n^j(\vec{P}_n, U_n)} d\ln P_n^j &= \sum_{j=a,m,s} \omega_n^j(\vec{P}_n, U_n)(1 - \sigma d\ln P_n^j) d\ln P_n^j \\
&= \sum_{j=a,m,s} \omega_n^j(\vec{P}_n, U_n) d\ln P_n^j - \sigma \sum_{j=a,m,s} \omega_n^j(\vec{P}_n, U_n)(d\ln P_n^j)^2 \\
&\simeq \sum_{j=a,m,s} \omega_n^j(\vec{P}_n, U_n) d\ln P_n^j,
\end{aligned}
$$

where the second term in the second line is negligible.

3.2.2 Decomposition

To highlight main channels through which shocks change steady states, we here assume balanced trade, i.e., $\phi_{n,t} = 0$ for all country n and period t, and fully flexible investment, i.e., $\lambda = 1$ (see (8)). The equivalent variation in (24) can be further decomposed into as follows:

$$
\begin{aligned}
\frac{EV_{n,t}}{E_{n,t}} = & \underbrace{\frac{1}{E_{n,t}} \sum_{j=a,m,s} \sum_{i=1}^{N} \left[EX_{in,t}^{j} \left(d\ln \tilde{c}_{n,t}^{j} + d\ln d_{in,t}^{j} - d\ln A_{n,t}^{j} \right) - IM_{ni,t}^{j} \left(d\ln \tilde{c}_{i,t}^{j} + d\ln d_{ni,t}^{j} - d\ln A_{i,t}^{j} \right) \right]}_{\text{Terms of trade effect}} \\
& + \underbrace{\frac{1}{E_{n,t}} \sum_{j=a,m,s} \sum_{i=1}^{N} EX_{in,t}^{j} \left[d\ln A_{n,t}^{j} - d\ln d_{in,t}^{j} + \gamma_{n,t}^{j} \left\{ \alpha_{n,t}^{j} d\ln K_{n,t} + (1-\alpha_{n,t}^{j}) d\ln L_{n,t} \right\} - \Gamma_{n,t}^{j} - (1-\gamma_{n,t}^{j}) \sum_{h=a,m,s} \frac{g_{n,t}^{jh} d\ln \kappa_{n,t}^{jh}}{1-\sigma^{j}} \right]}_{\text{Volume of trade effect}} \\
& \underbrace{- \frac{P_{n,t}^{K}}{E_{n,t}} \left[K_{n,t+1} d\ln K_{n,t+1} - (1-\delta_n) K_{n,t} d\ln K_{n,t} + I_{n,t} \sum_{j=a,m,s} \frac{g_{n,t}^{Kj} d\ln \kappa_{n,t}^{Kj}}{1-\sigma^{K}} \right]}_{\text{Investment effect}},
\end{aligned}
$$

where $EX_{in,t}^{j} = \pi_{in,t}^{j} X_{i,t}^{j}$ is the exports of country n to i in sector j in period t; $IM_{ni,t}^{j} = \pi_{ni,t}^{j} X_{n,t}^{j}$ is the imports of country n from i in sector j in time t; the term Γ_{n}^{j} summarizes changes in the parameter $\gamma_{n,t}^{j}$ governing the cost share of intermediate inputs:

$$
\Gamma_{n,t}^{j} \equiv \gamma_{n,t}^{j} [\alpha_{n,t}^{j} \ln r_{n,t} + (1-\alpha_{n,t}^{j}) \ln w_{n,t} - \ln \xi_{n,t}^{j}] d\ln \gamma_{n,t}^{j}.
$$

The first term measures the terms of trade effect, which is a sum of changes in bilateral export prices and import prices at sector level weighted by bilateral exports and imports, respectively. The welfare measure increases as the terms of trade improves from a rise in export prices or a fall in import prices. The second term measures the volume of trade effect, capturing the positive effect of export growth on welfare by raising income. It increases with the sectoral productivity growth and the endowment growth and decreases with the growth of sectoral trade costs. The final term represents the investment effect. This is negative simply because more investment reduces income and thus consumption expenditure. Similar formulas can be found in Caliendo and Parro (2015); and Hsieh and Ossa (2016).

4 Calibration and Solution Algorithm

We bring the model to the data for the global economy. We first describe our main data sources and then discuss the calibration of the structural parameters. We then present the solution algorithm for computing transition paths.

4.1 Data

Our primary data source is the World Input-Output Database (WIOD) Release 2016 and the Long-Run WIOD (Woltjer et al., 2021; Timmer et al., 2015), which allows us to observe the intermediate input uses across different countries and sectors of both origin and destination. By merging the two datasets, we constructed a database that covers half the century, 1965–2014. Our empirical exercise encompasses 24 countries (see Table 1) and the rest of the world (RoW).

Table 1: List of Countries

Australia	Canada	Spain	Greece	Japan	Portugal
Austria	China	Finland	India	Korea	Sweden
Belgium	Germany	France	Ireland	Mexico	Taiwan
Brazil	Denmark	UK	Italy	Netherlands	USA

They are the listed countries in the Long-Run WIOD, and we moved Hong Kong to the RoW. We aggregate the ISIC industries into three categories as in Table 2. We label D15-D16 Food, Beverages, and Tobacco as agriculture instead of manufacturing due to the nature of its products. Construction and utility supply (e.g., electricity, gas, and water supply) is categorized as a service.[5] We complement the WIOD data with the Penn World Table (PWT) 10.0 (Feenstra et al., 2015) and CEPII Gravity database (Mayer and Zignago, 2011).

4.2 Structural Parameters

We begin with discussing our calibration of the parameters in preferences. The discount factor β is set at 0.96 to be consistent with a real interest rate of 4 percent per year. We set the inter-temporal elasticity of substitution $\psi = 2$ following Ravikumar et al. (2019). For parameters in the period utility, we choose the elasticities of substitution across sectors $\sigma = 0.5$, and the degree of nonhomotheticity $\epsilon^a = 0.05$ in agriculture, $\epsilon^m = 1$ in manufacturing, and $\epsilon^s = 1.2$ following Comin et al. (2021). $\sigma < 1$ implies that sectoral goods are compliments, and, therefore, the Baumol effect is at work. Values of ϵs suggest that agriculture is a necessity, service is a luxury, and service starts with a luxury and then becomes a necessity as the consumption expenditure rises.

Value-added share in production function $\gamma^j_{n,t}$ is directly observed in the IO table. Capital share within value-added $\alpha^j_{n,t}$ is calibrated as one minus labor share, which is obtained from the PWT. Since the PWT does not provide the sectoral labor share, we apply the common value across sectors for each year and country. We set the elasticity of substitution across intermediate inputs $\sigma^j = 0.38$ for all j following Atalay (2017). For the capital goods production, we set the elasticity of substitution $\sigma^K = 0.29$ following Sposi et al. (2021). Shape parameters of the Fréchet distribution, i.e., trade elasticities, are chosen as $\theta^a = 8.11$ and $\theta^m = \theta^s = 4.55$. Elasticities for the goods sectors are calibrated based on the estimates of Caliendo and Parro (2015), and we set the elasticity for the service sector to be the same as the manufacturing sector. We will discuss the calibration of productivity and exogenous demand shifters below.

We set the adjustment cost elasticity in the low of motion for capital $\lambda = 0.75$ following

[5] Whether the construction and utilities are categorized as manufacturing, service, or an independent sector differs across previous studies. For example, Sposi (2019); Sposi et al. (2021), Uy et al. (2013), Smitkova (2023), Lewis et al. (2022) include construction in the service sector, while Święcki (2017), García-Santana et al. (2021), Herrendorf et al. (2014, 2021), and Betts et al. (2017) include in the manufacturing sector.

Table 2: Three Sectors and Corresponding ISIC3 Codes

Sector	ISIC3	Description
Agriculture	A to B	Agriculture, Hunting, Forestry and Fishing
	C	Mining and Quarrying
	D15 to 16	Food, Beverages and Tobacco
Manufacturing	D17 to 19	Textiles, Textile, Leather and Footwear
	D21 to 22	Pulp, Paper, Paper, Printing and Publishing
	D23	Coke, Refined Petroleum and Nuclear Fuel
	D24	Chemicals and Chemical Products
	D25	Rubber and Plastics
	D26	Other Non-Metallic Mineral
	D27 to 28	Basic Metals and Fabricated Metal
	D29	Machinery, Nec
	D30 to 33	Electrical and Optical Equipment
	D34 to 35	Transport Equipment
	D n.e.c.	Manufacturing, Nec; Recycling
Service	E	Electricity, Gas and Water Supply
	F	Construction
	G	Wholesale and Retail Trade
	H	Hotels and Restaurants
	I60 to 63	Transport and Storage
	I64	Post and Telecommunications
	J	Financial Intermediation
	K	Real Estate, Renting and Business Activities
	L to Q	Community Social and Personal Services

Eaton et al. (2016) and the depreciation rate of capital $\delta_{n,t}$ is obtained from the PWT.

4.3 Path of Shocks

We back out the trade cost *à la* Head and Ries (2001) assuming the symmetry:

$$d^j_{ni,t} = \left(\frac{\pi^j_{ni,t} \pi^j_{in,t}}{\pi^j_{ii,t} \pi^j_{nn,t}} \right)^{1/(2\theta^j)},$$

where the right-hand-side variables are all observable in the IO table. We calibrate the average productivity $A^j_{n,t}$, i.e., Fréchet location parameters, following Levchenko and Zhang (2016). To begin with, we express the trade share normalized by its own trade share as follows:

$$\frac{\pi^j_{ni,t}}{\pi^j_{nn,t}} = \frac{\left(\frac{\tilde{c}^j_{i,t} d^j_{ni,t}}{A^j_{i,t}}\right)^{-\theta^j}}{\left(\frac{\tilde{c}^j_{n,t}}{A^j_{n,t}}\right)^{-\theta^j}} = \left(\tilde{c}^j_{i,t}/A^j_{i,t}\right)^{-\theta^j} \times \left(\tilde{c}^j_{n,t}/A^j_{n,t}\right)^{\theta^j} \times \left(d^j_{ni,t}\right)^{-\theta^j}.$$

Taking the log of both sides gives:

$$\ln\left(\frac{\pi^j_{ni,t}}{\pi^j_{nn,t}}\right) = \ln\left(\tilde{c}^j_{i,t}/A^j_{i,t}\right)^{-\theta^j} + \ln\left(\tilde{c}^j_{n,t}/A^j_{n,t}\right)^{\theta^j} - \theta^j \ln\left(d^j_{ni,t}\right).$$

We then express the log of the iceberg trade cost using the set of bilateral observables as:

$$\ln\left(d^j_{ni,t}\right) = \text{dist}^j_{k(ni)} + \text{CB}^j_{ni} + \text{CU}^j_{ni,t} + \text{RTA}^j_{ni,t} + ex^j_{it} + \nu^j_{ni,t},$$

where $\text{dist}^j_{k(ni)}$ is the contribution to trade costs of the distance between n and i being in a certain interval[6], CB^j_{ni} is the indicator if the two countries n and i share the border, $\text{CU}^j_{ni,t}$ indicates if they are in the currency union, $\text{RTA}^j_{ni,t}$ indicates if they are in a regional trade agreement (WTO definition), ex^j_{it} is the exporter fixed effects,[7] and $\nu^j_{ni,t}$ is the bilateral error term. We plug this into the trade share equation (15) and estimate the following using the Pseudo Poisson Maximum Likelihood (PPML) for each sector j while pooling all sampled countries and years:

$$\begin{aligned}\ln\left(\frac{\pi^j_{ni,t}}{\pi^j_{nn,t}}\right) = & \underbrace{\ln\left(\left(\tilde{c}^j_{i,t}/A^j_{i,t}\right)^{-\theta^j} - \theta^j ex^j_{it}\right)}_{\text{exporter-year F.E.}} + \underbrace{\ln\left(\tilde{c}^j_{n,t}/A^j_{i,t}\right)^{\theta^j}}_{\text{importer-year F.F.}} \\ & \underbrace{-\theta^j \ln\left(\text{dist}^j_{k(ni)} + \text{CB}^j_{ni} + \text{CU}^j_{ni,t} + \text{RTA}^j_{ni,t}\right)}_{\text{Bilateral observables}} - \theta^j \nu^j_{ni,t}.\end{aligned}$$

Estimating the gravity equation above allows us to identify the technology-cum-unit-cost term, $\ln\left(\tilde{c}^j_{n,t}/A^j_{i,t}\right)^{\theta^j}$, for each county and year as an importer-year fixed effect, relative to the reference country and year (US in 1965), which we denote by $S^j_{nt} = \left(\tilde{c}^j_{n,t}/A^j_{n,t}\right)^{-\theta^j} / \left(\tilde{c}^j_{US,1965}/A^j_{US,1965}\right)^{-\theta^j}$. Then, we follow Shikher (2013) to recover the sectoral price indices as follows. First, we define

[6] We follow Eaton and Kortum (2002) and intervals are defined, in miles, $[0, 350]$, $[350, 750]$, $[750, 1500]$, $[1500, 3000]$, $[3000, 6000]$, $[6000, \max]$

[7] We follow Waugh (2010).

the own trade share relative to the ones of the reference country and year:

$$\frac{\pi^j_{nn,t}}{\pi^j_{US,US,1965}} = \frac{\left(\tilde{c}^j_{n,t}/A^j_{n,t}\right)^{-\theta^j}}{\left(\tilde{c}^j_{US,1965}/A^j_{US,1965}\right)^{-\theta^j}} \left(\frac{P^j_{n,t}}{P^j_{US,1965}}\right)^{\theta^j}.$$

Since the first term in the right-hand-side is already identified as the importer fixed effect S^j_{nt} in the gravity regression, we can recover the sectoral price indices as follows, for given trade elasticity θ^j:[8]

$$\frac{P^j_{n,t}}{P^j_{US,1965}} = \left(\frac{\pi^j_{nn,t}}{\pi^j_{US,US,1965}} \frac{1}{S^j_{nt}}\right)^{1/\theta^j}.$$

Being armed with the sectoral price indices, we back out the exogenous demand shifter for intermediate inputs, $\kappa^{jh}_{n,t}$, by solving the system of equations for each j, n, and t:

$$g^{j,h}_{n,t} = \frac{\kappa^{j,h}_{n,t}(P^h_{n,t})^{1-\sigma^j}}{\sum_{h'=a,m,s} \kappa^{j,h'}_{n,t}(P^{h'}_{n,t})^{1-\sigma^j}}.$$

by restricting $\sum_{h'} \kappa^{j,h'}_{n,t} = 1$ for each j, n, and t. The left-hand-side of the equation, $g^{j,h}_{n,t}$, is the share of expenditure spent on input from sector h in total input expenditure of j, which is directly observed in the IO table. After obtaining $\kappa^{jh}_{n,t}$, we can recover the CES price index for the composite intermediate good $\xi^j_{n,t}$ according to (13). We analogously backout the exogenous demand shifter in the capital goods production function, $\kappa^{Kh}_{n,t}$, by solving the system of equations for each n and t:

$$g^{K,h}_{n,t} = \frac{\kappa^{K,h}_{n,t}(P^h_{n,t})^{1-\sigma^K}}{\sum_{h'=a,m,s} \kappa^{K,h'}_{n,t}(P^{h'}_{n,t})^{1-\sigma^K}}.$$

by restricting $\sum_{h'} \kappa^{K,h'}_{n,t} = 1$.

Having $\xi^j_{n,t}$ in hand, we can compute the cost of the input bundle according to (12). To recover wages, we compute the wage bill of each economy by multiplying the labor share obtained from the PWT and the economy-wide value-added computed based on the WIOD. We then divide the wage bill by the total population of the country sourced from the PWT. For the rental price of capital, we divide the return to capital (i.e., total value-added minus the wage bill) by the capital stock of the country obtained from the PWT. Then, we can recover

[8] Note that the price indices are recovered relative to the US in 1965 for each sector. That means the US price index is 1 for all sectors in 1965.

the productivity $A^j_{n,t}$ by:[9]

$$A^j_{n,t} = (S^j_{n,t})^{1/\theta^j} \left(\frac{\tilde{c}^j_{n,t}}{\tilde{c}^j_{US,1965}} \right).$$

Given the data on trade surplus and GDP across countries, we seek to calibrate the share of payment to the global portfolio in aggregate income $\phi_{n,t}$. Let $TS_{n,t}$ and $GDP_{n,t}$ denote the trade surplus and GDP in country n and period t, respectively, which are directly observed in the IO table.[10] Then substituting (23) into (22) yields

$$TS_{n,t} = \phi_{n,t} GDP_{n,t} - L_{n,t} \frac{\sum_{n'=1}^N \phi_{n',t} GDP_{n',t}}{L_t},$$

where $L_t = \sum_{n'=1}^N L_{n',t}$ is the global population. Letting $\mu_{n,t} = L_{n,t}/L_t$, we have

$$\frac{TS_{n,t}}{\mu_{n,t}} + \sum_{n'=1}^N \phi_{n',t} GDP_{n',t} = \frac{\phi_{n,t} GDP_{n,t}}{\mu_{n,t}}.$$

Define Ψ_t, and Ξ_t by

$$\Psi_t = \begin{bmatrix} GDP_{1,t} & \cdots & GDP_{N,t} \\ \vdots & & \vdots \\ GDP_{1,t} & \cdots & GDP_{N,t} \end{bmatrix}, \qquad \Xi_t = \begin{bmatrix} TS_{1,t}/\mu_{1,t} \\ \vdots \\ TS_{N,t}/\mu_{N,t} \end{bmatrix},$$

and, let Υ_t be the $N \times N$ diagonal matrix with diagonal element $GDP_{n,t}/\mu_{n,t}$. Then, we can recover $\vec{\phi}_t = (\phi_{1,t}, \cdots, \phi_{N,t})^T$ by solving:

$$\vec{\phi}_t = (\Upsilon_t - \Psi_t)^{-1} \Xi_t.$$

4.4 Values of Shocks

Before moving on to the quantitative results, we summarize the baseline shocks we calibrated above. Figure 2 shows the evolution of sectoral productivity in four countries, China, Germany, Japan, and the US. We normalize the productivity in 1965 to be 1 and take the moving average over 3 years to remove the noise. In Germany, Japan, and the US, the productivity of manufacturing increased more than that of the service sector over the period. For example, manufacturing productivity in the US increased by a factor of 1.8 while the service sector productivity increased by a factor of 1.3. The higher productivity growth in manufacturing than service implies that the expenditure share on manufacturing may drop due to the Baumol effect, even if we do not cosinder impacts of international trade and non-homotheticity

[9]By construction, sectoral productivity takes 1 for the US in 1965 in all sectors.

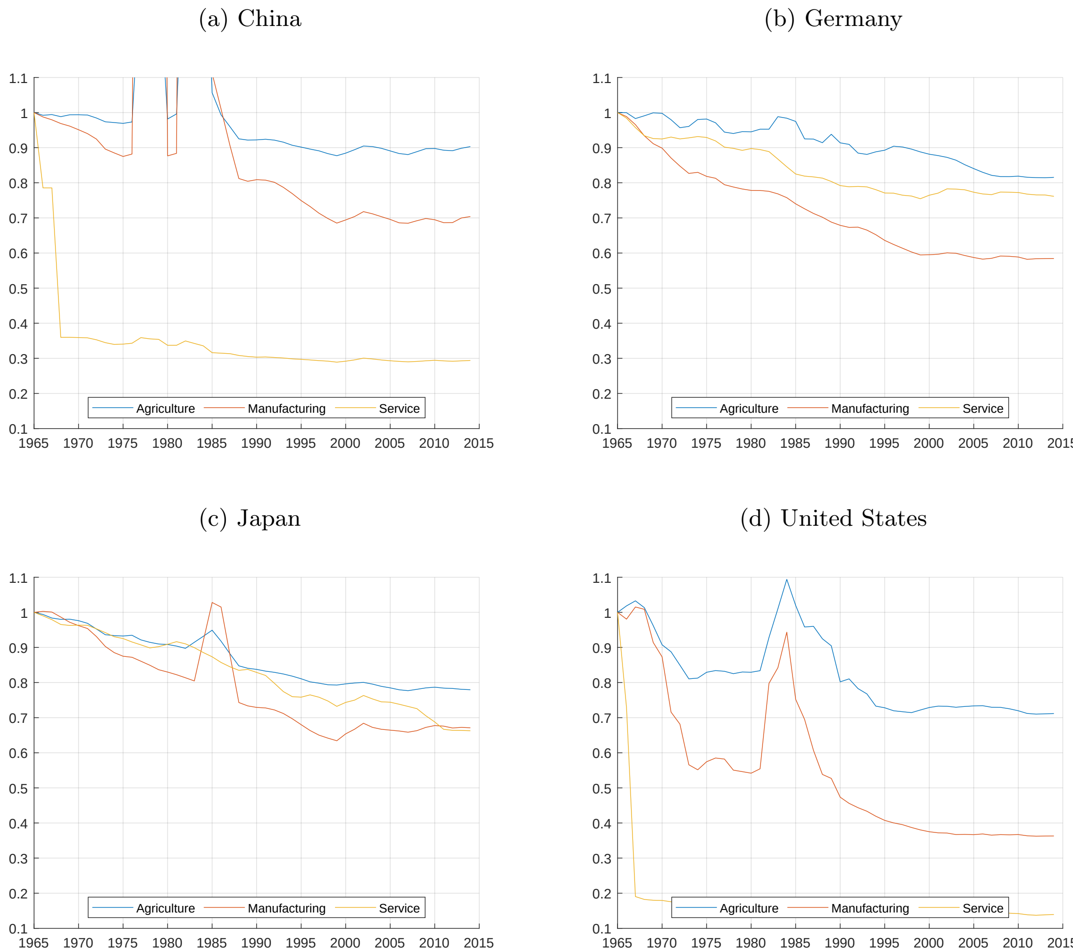
[10]Note that $TS_{n,t} = \sum_{a,m,s} \gamma^j_{n,t} Y^j_{n,t} - (E_{n,t} + P^K_{n,t} I^K_{n,t})$ and $GDP_{n,t} = r_{n,t} K_{n,t} + w_{n,t} L_{n,t}$.

Figure 2: Productivity Evolution (1965=1, Moving Average)

preference-driven demand change. In China, service sector productivity grew more, by a factor of 5.5, than manufacturing productivity, by a factor of 4.5. Despite the relatively lower growth in manufacturing productivity to service sector, the manufacturing growth is much higher in level than those in Germany, Japan and the US.

Figure 3 summarizes the evolution of trade costs in the four countries. Here we compute the simple aritmetic average of the bilateral trade costs for each country. Again, we normalize the values in 1965 to be 1 and take the moving average over 3 years. Over the five decades, China and the US observed a sharp drop in service trade costs, almost 70% in China and 90% in the US. However, the major drop in the service trade costs in the two countries happened between 1969 and 1970 of the sample period, and it has been more stable since then. After 1970, service trade costs have dropped only by 20% in China and 25% in the US, which is lower than the decline in manufacturing trade costs over the entire sampled period (30% in

Figure 3: Evolution of Trade Costs (1965=1, Moving Average)

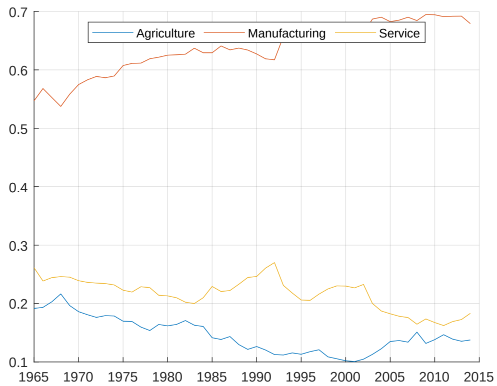


China and 65% in the US). Germany and Japan also show a large decline in manufacturing trade costs, by 40% and 30%, respectively.

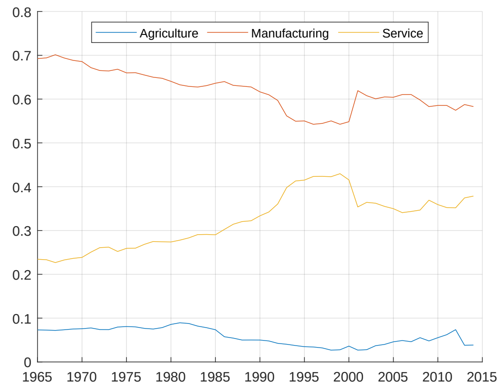
Figure 4 and 5, respectively, demonstrate the intermediate input cost shares for the manufacturing sector and for the capital good production, which are used for the calibration of $\kappa_{n,t}^{h,j}$ and $\kappa_{n,t}^{K,j}$. Except for China, in all three countries, service inputs are becoming more important in manufacturing production. As we saw above, since the productivity of manufacturing grows faster than service sector and the elasticity of substitution across inputs is less than one, the Baumol effect may be a determinant of the increasing share of of service. Growing share of service is also observed for the capital good production in some countries. In addition to the Baumol effect, the nonhomotheticity in the production function may be another reason for the rising share of service. This is beyond the scope of this paper but is an interesting topic for future research.

Figure 4: Cost Shares in Manufacturing Production

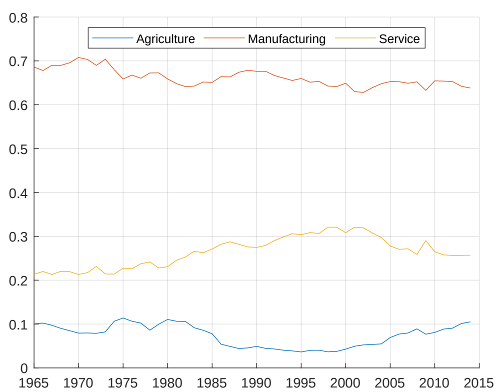
(a) China



(b) Germany



(c) Japan



(d) United States

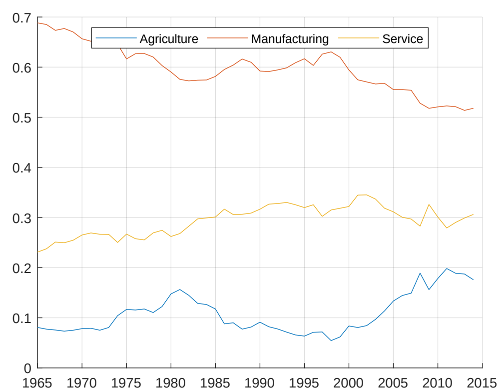
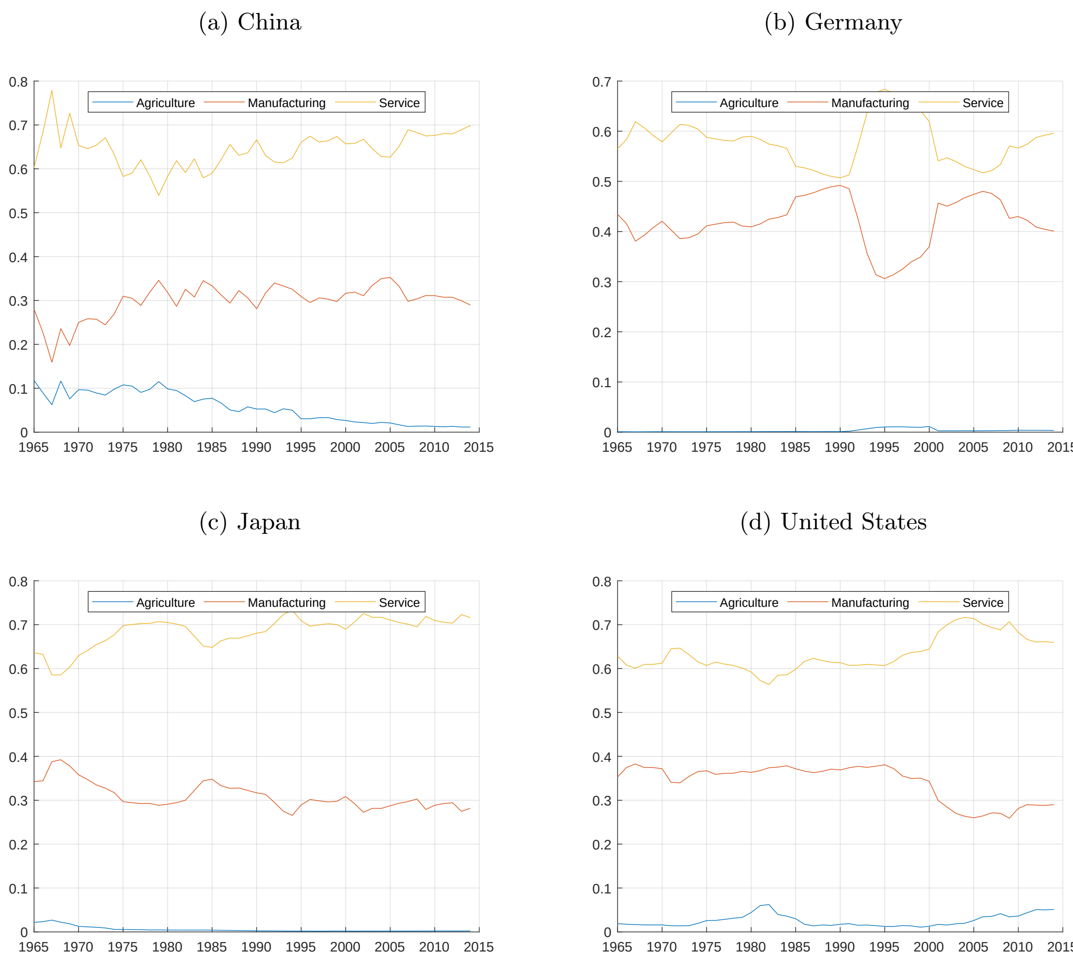


Figure 5: Cost Shares in Capital Good Production



4.5 Solution Algorithm

We solve the equilibrium transition path forward in relative changes. For given values of equilibrum variables in the initial period (1965), including wages, rental rate of capital, price indices, final consumption expenditure, etc., we guess a vector of wages (in relative changes) for the next period. Then, we solve for rental rate, the cost of input bundle, trade shares, and sectoral price index *à la* Alvarez and Lucas (2007). We then solve the intra-temporal optimization prpoblem to obtain the sectoral expenditure shares, and then solve the inter-temporal optimization probelm according to the Euler equation. We then update the wage and repeat the steps until we find the fixed point. After the wage vector converges, we compute the current period equilibrium outcomes by multiplying the equilibrium variables in relative changes by the initial values. We then move on the next period and repeat. After 2014, we assume that the all the fundamentals and shocks are constant at the 2014 level.

5 Quantitative Results

This section presents the quantitative results of the calibrated model.

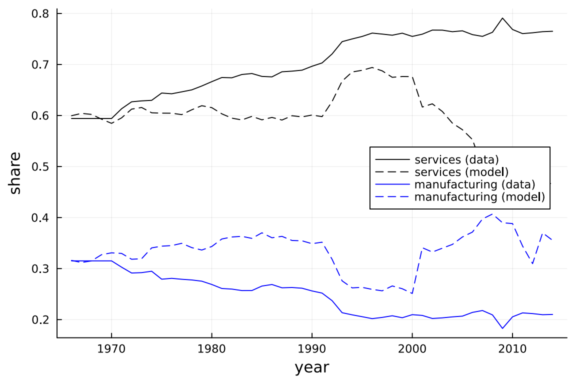
5.1 Fit of the Baseline Model

We first show the baseline results. To examine the model's ability to match the data, Figure 6 compares the model-implied (dashed line) value-added share in manufacturing (blue) and service (black) with the data counterpart (solid line) for three advanced economies, Germany, Japan, and the US. In the US, the model captures the declining share of manufacturing and rising share of service in value-added. The model suggests that the manufacturing value added share drops from 25.0% (data 23.5%) in 1965 to 2.9% (10.1%) in 2014. The service value added share increases from 68.2% (69.8%) to 88.8% (84.0%). In Germany and Japan, the model does not fit to the data as well as in the US, both in terms of level and trend. In those two countries, the model underpredicts (overpredicts) the service (manufacturing) value added share and fails to capture the rising (declining) service (manufacturing) sector.

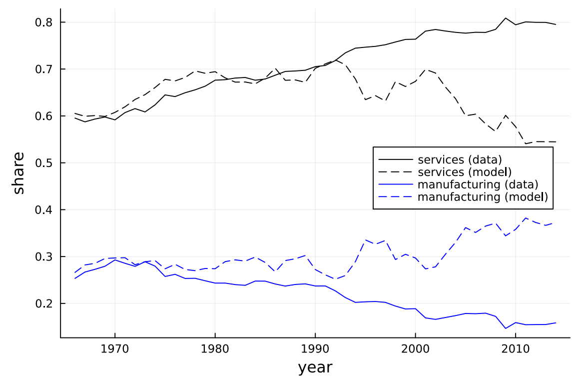
Next, we show the expenditure share in final consumption $\omega_{n,t}^{j}$ implied by the model and the data (Figure 7). In all of the three countries presented, the model fits the manufacturing expenditure share well while it does not capture the rising share in service expenditure share. An underlying reason of this failure is that the model predicts the increasing saving rate over time as presented in Figure 8. The saving rate is computed as the fraction of income used for the investment. While in the data, saving rate is always below 30% in all the three countries and slightly declining over time, the model predicts the saving rate rises to almost 90% over time. In our model, as implied by (2), a consumer increases the consumption for service as the per capita real consumption ($C_{n,t/L_{n,t}}$) rises *ceteris paribus*. Although the

Figure 6: Model Fit: Sectoral Value Added Share in GDP

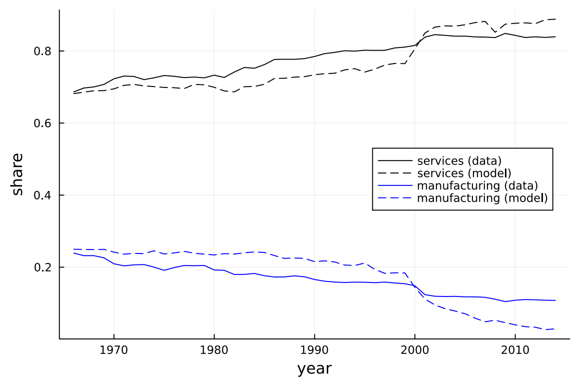
(a) Germany



(b) Japan



(c) US

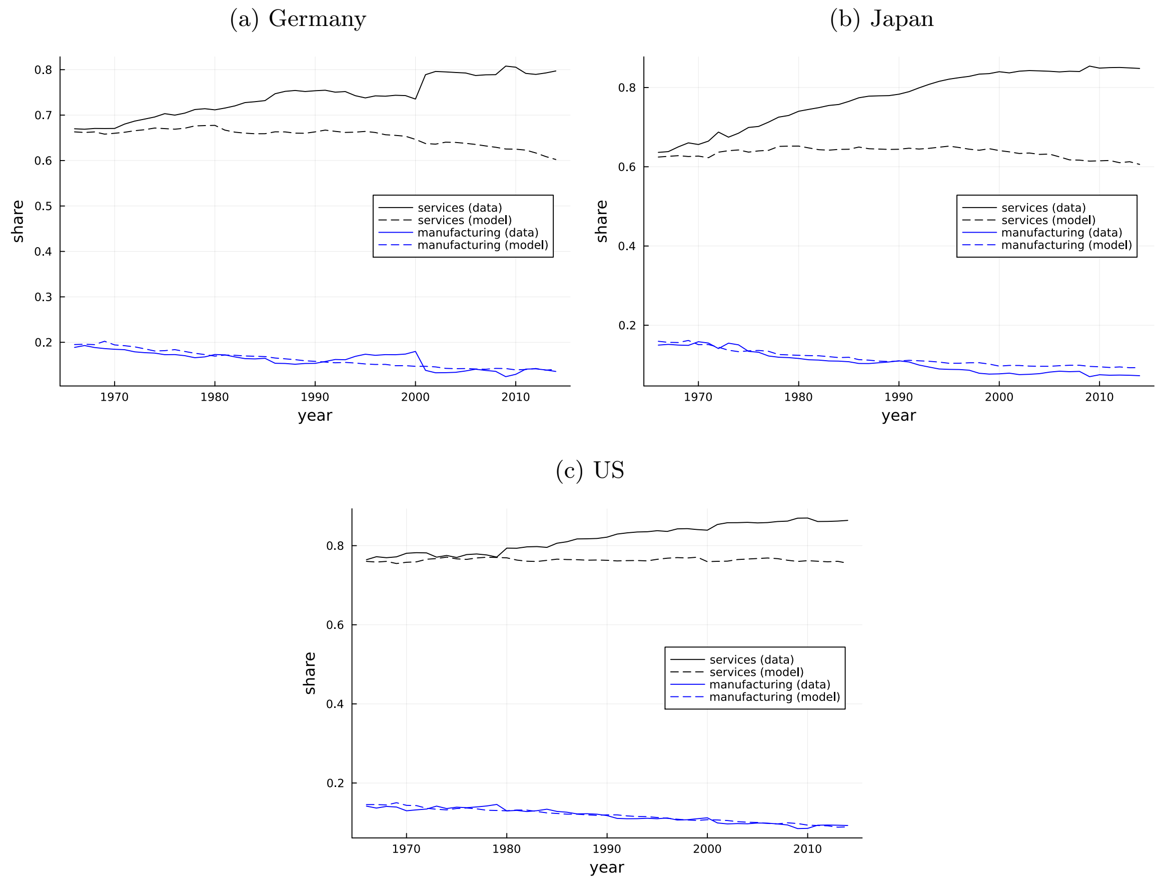


model-implied national income is growing in those countries over time, the rising saving rate dampens the consumption. As a result, model does not generate the rising share of service in final consumption. We plan to improve the fit of the model by introducing the intertemporal preference shocks as in Eaton et al. (2016) and Sposi et al. (2021).

Figure 9 compares the model-implied sectoral share in investment cost, $g_{n,t}^{Kj}$ with the data. The model fits the data well in all three countries. The better performance of the model in explaining the investment cost share is not surprising since the exogenous demand shifter $\kappa_{n,t}^{K,j}$ is calibrated to match the data.

Finally, Figure 10 shows the evolution of sectoral price indices in the three countries implied by the model with all prices being normalized to be one in 1965. In all countries, manufacturing price drops the most among three sectors, which suggests that the Baumol effect is at work. We will come back to this point in the counterfactual analysis. .

Figure 7: Model Fit: Sectoral Expenditure Share in Final Consumption



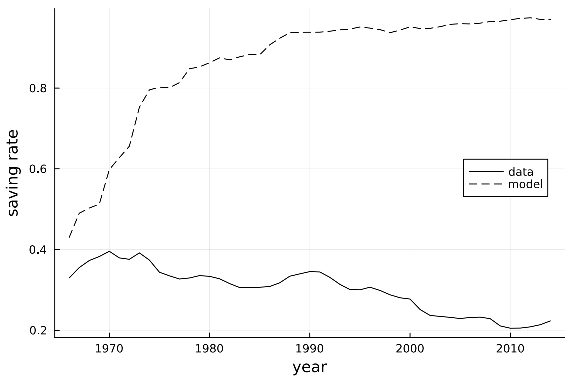
5.2 Counterfactual: Keeping Trade Costs Fixed at 1965 Level

Now we will use the model to understand the joint role of international trade and structural change in accounting for the change in sectoral composition among advanced countries. Specifically, we consider how the world would have evolved in a counterfactual scenario where trade costs remained fixed at their 1965 levels. Figure 11 compares the counterfactial value-added share (dashed line) in manufacturing and service with the baseline result (solid line) for three countries, Germany (blue), Japan (green), and the US (black).

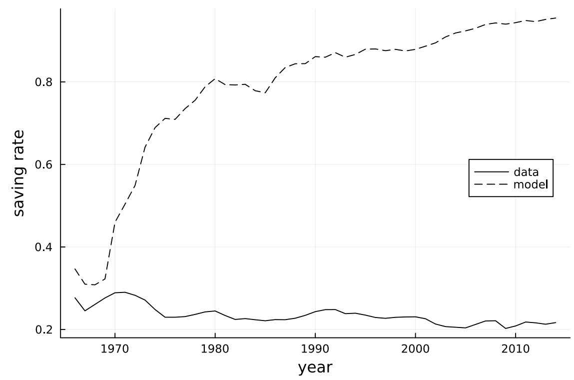
Two interesting patterns are evident from Figure 11. First, the effect of reducing trade costs at the 1965 to the current level has become increasingly important over time in all the three countries and particularly so since the late 1990s. Here we will take a closer look at the US, whose transition path for the baseline fits the data the best. The counterfactual changes in manufacturing value-added share remained in a 7% point range before 2000, but they have sharply increased since then and recorded 17.2% point in 2014. A more sudden increase in the impact of globalization is observed in Japan, where reductions in trade costs have changed

Figure 8: Model Fit: Saving Rate

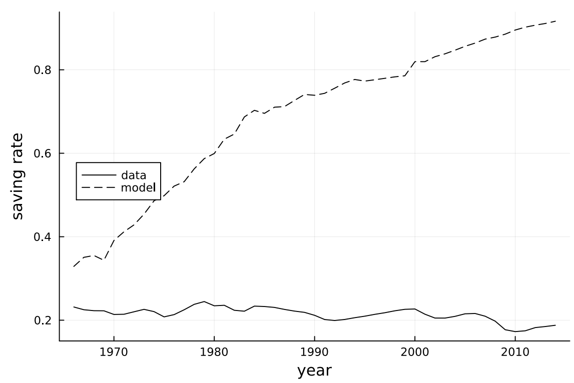
(a) Germany



(b) Japan



(c) US



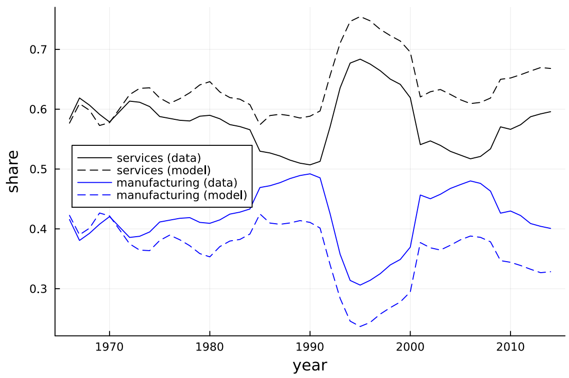
the manufacturing value-added share on average by 1.6% point in 1985-1994, 6.0% point in 1995-2004, and 13.0% point in 2005-2014. These results reflect the fact that the speed of globalization was not uniform over the last five decades and has accelerated since around the late 1990s. The growing pace of globalization in the last three decades is emphasized by a number of studies, e.g., "the Second Unbundling" put forward by Baldwin (2016).

The other interesting pattern is that the impacts of globalization are heterogeneous across countries. Namely, the counterfactual transition paths relative to the ones of baseline suggests that the reduction in trade costs from the 1965 to the current level *contacted* US manufacturing for the entire sample period, while it *expanded* manufactuting in Germany after 2004 except for 2012 and in Japan after 1992. To highlight the period between 2001 and 2007, when the China shock stands out (Autor et al., 2013), the *lost share* in the US manufacturing is on average 12.1% point, while the *gained share* in Germany and Japan on average 0.7% point and 8.3% point respectively.

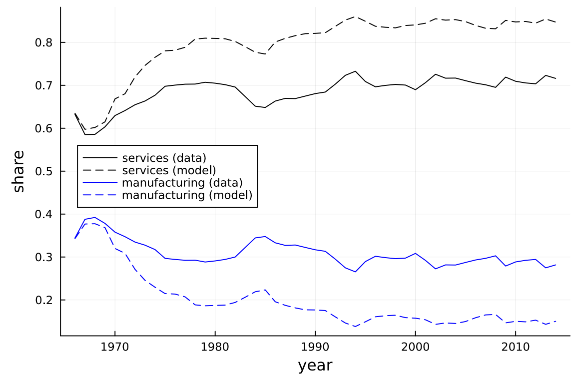
These contrasting results can be understood with the help of Figures 10 and 12, which show

Figure 9: Model Fit: Investment Cost Share

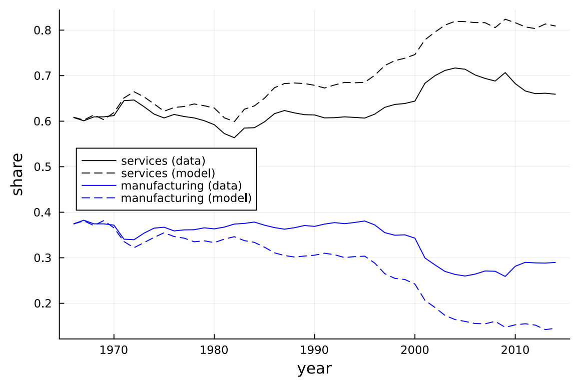
(a) Germany



(b) Japan



(c) US

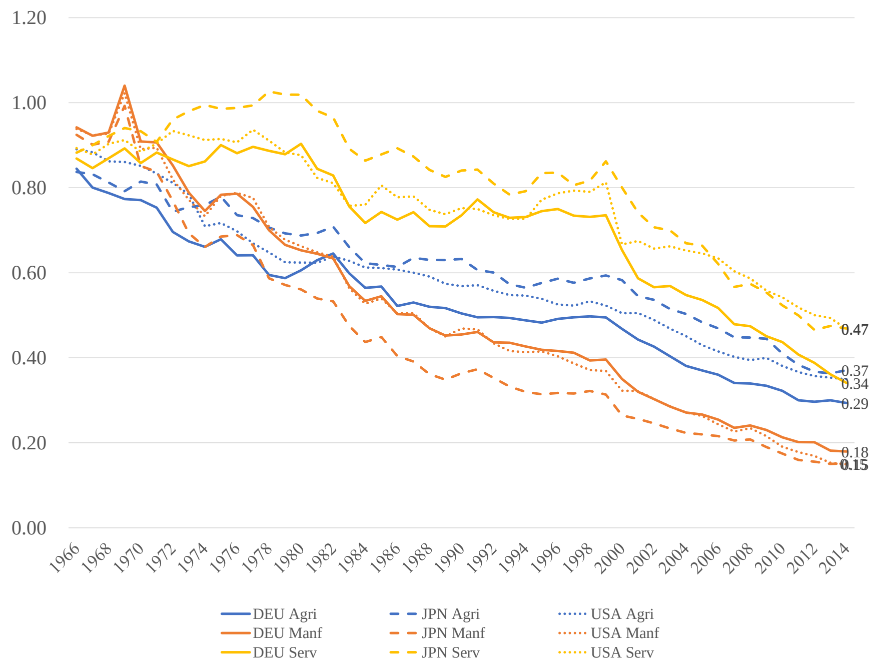


respectively the baseline and counterfactual sectoral prices over time. In the US, the trade cost reductions lead to on average 23.0% point drop in manufacturing price and 2.5% point rise in service price during 2001-2007. The changes in sectoral price can be attributed to the two key forces: (a) the comparative disadvantage of the US manufacturing and (b) reductions in trade costs biased toward service in the US. More specifically, (a) the US productivity of manufacturing relative to service was higher than other countries (see Figure 2);[11] (b) trade cost reductions in the US manufacturing relative to service were much greater than those in Germany and Japan (see Figure 3). These two factors determine the changes in relative price and lead the US to contract the comparative *dis*advantage manufacturing sector and expand the comparative advantage service sector. Moreover, the changes in relative price strengthen the shift in sectoral composition through the Baumol effect; the US consumers with a sufficiently low elasticity of demand spend less on manufacturing and more on service.

In Germany, the sectoral shift from service to manufacturing follows a precisely opposite

[11]We see from Figure 2 that manufacturing sector is 1.4 times more productive than service sector in the US in 2005. This relative productivity is lower than that in Germany (1.52) and in Japan (1.47).

Figure 10: Transition of Sectoral Prices under Baseline Equilibrium (1965=1)



mechanism compared to that observed in the US. The counterfactual reductions in trade costs were especially significant in manufacturing (see Figure 3), pushing Germany to grow the comparative advantage manufacturing sector. This is translated into a higher relative price of manufacturing to service and thus a greater manufacturing value-added share, facilitated by the Baumol effect.[12]

6 Conclusion

We developed a dynamic general equilibrium model that features international trade, capital accumulation, sector-biased productivity growth and non-homothetic preferences to disect the evolution of sectoral composition in the global economy. We bring the model to the data for the world economy with 24 countries over the period of 1965–2014. Our calibrated model captures the declining share of manufacturing and rising share of service in value-added in the US. We conducted a counterfactual experiment to explore what the economy would look like if trade costs had remained at the 1965 level. The results show that the impact of globalization on the sectoral composition of advanced countries has been increasingly important and the impact is heterogeneous across countries. In particular, reducing trade costs at the 1965 to the current level would result in the US losing the manufacturing value-added share and

[12] A more complex mechanism operates in Japan as it increases manufacturing value-added share, yet reduces manufacturing price after the counterfactual trade cost reductions.

Figure 11: Counterfactual Value-Added Share in Manufacturing (Fixing Trade Costs)

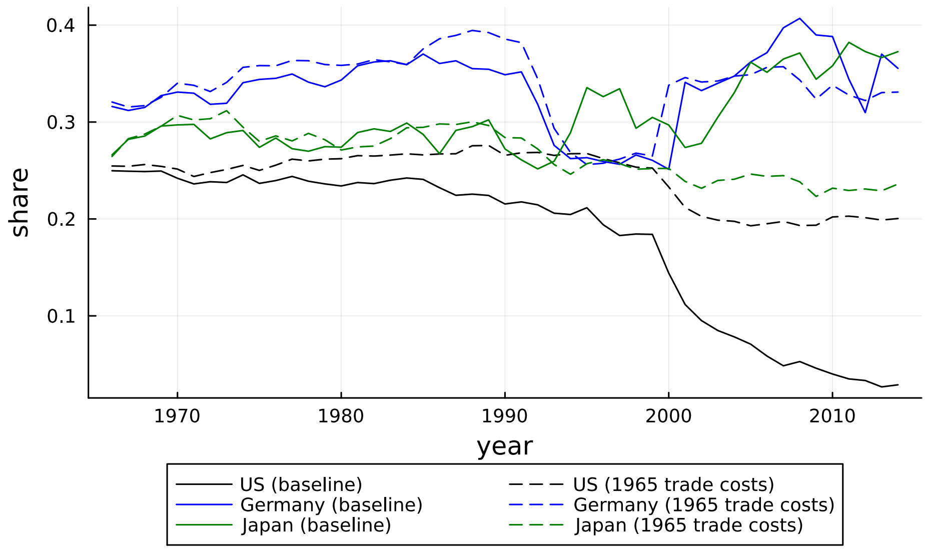
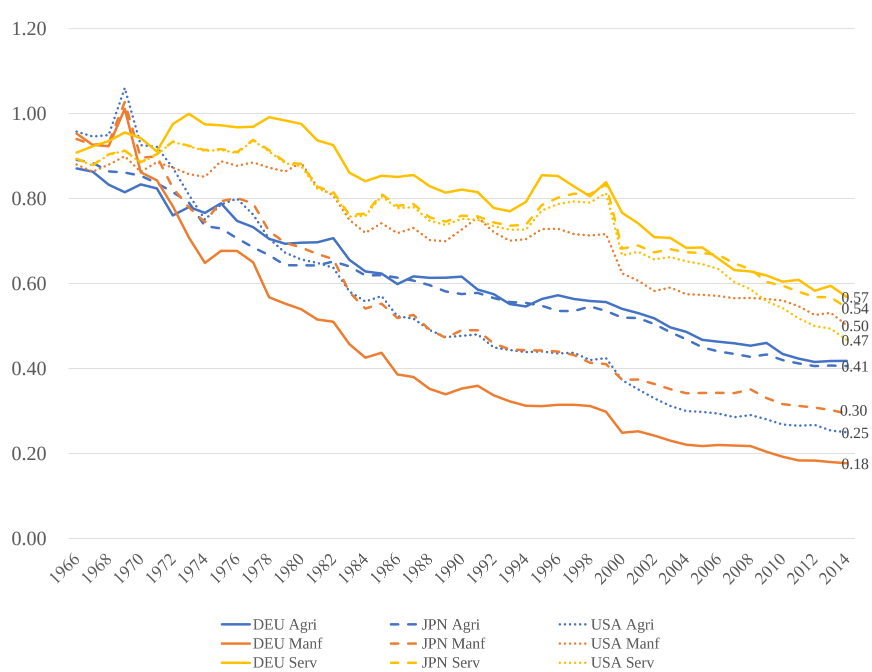


Figure 12: Transition of Sectoral Prices under Counterfactual (1965=1)



gaining the service value-added share. The opposite pattern is observed for Germany and Japan. One may attribute the recent decline in manufacturing in advanced countries largely to the integration of emerging economies into the world trade system, typically referred to as "China shock" story. Our counterfactual exercise supports the argument in the US case, but contradicts it in the cases of Germany and Japan. We put a great emphasis on the role of structural change and its interaction with trade in shaping the sectoral composition of a country from the long-term perspective of economic growth.

A few more next steps are in order. First of all, due to the increasing saving rate implied by the model, the model fails to match the evolution of expenditure shares across sectors. We plan to fix the too-high saving rate by introducing time-country specific demand shifter as in Eaton et al. (2016); Sposi et al. (2021) to better fit the model to the data. Then we will provide a more detailed decomposition of the effect of falling trade costs on sectoral composition according to the analytical formulas developed in Section 3. Our expected results answer questions such as: to what extent globalization would reduce manufacturing if none of the forces of structural change were in operation (e.g., non-homotheticity of consumer preferences); whether the decline in manufacturing resulting from globalization has similar welfare implications to the one resulting from structural change. Furthermore, we plan to apply our framework to study a few globalization episodes mentioned in Introduction, in particular, the impact of the eastward enlargement of the EU in 2004 and 2007 on sectoral composition and trade patterns among the EU member states.

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