The Sooner, The Better?
The Optimal Timing of Trade Liberalization for Low-income Countries

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Abstract

What is the optimal timing for a low-income country to liberalize trade? Is the gain from trade large enough for a low-income country to give up the opportunity to develop industries at their early stage? To address these questions, I construct a three-sector model in which the manufacturing sector features spillovers in productivity growth and organizational capital enhancement via technology choice, and the government chooses when to liberalize trade. In addition to the static gain from trade and the dynamic cost of giving up an infant industry, this paper contributes to the literature by highlighting one more dynamic cost: time to rebuild the manufacturing production capacity. Empirically, I find that the manufacturing sector plays a key role in driving economic growth, and faster GDP growth is associated with a larger worker inflow in the manufacturing sector for low-income countries after their World Trade Organization (WTO) accession. The calibration exercise shows that 80.5% (62 out of 77) of my sample countries can improve the welfare of the household by postponing the timing of WTO accession. Among these 62 countries, the median difference to optimal timing is 8 years and the median consumption equivalent variation under optimal liberalization timing is 0.0856%.

Keywords: structural transformation, trade liberalization, economic development, organizational capital, learning-by-doing

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1 Introduction

The timing of trade liberalization has long been a topic of debate, especially for low-income countries, where policymakers must balance the benefits of global market access with the need to nurture domestic industries. International trade promotes specialization, allowing countries to produce according to their comparative advantage, generating gains from trade. However, instant and uniform trade liberalization can be problematic, particularly for economies with infant industries that benefit from temporary protection or gradual liberalization (Melitz (2005)). If these infant industries have positive spillover in productivity, then the early liberalization might destroy these infant industries leading to a persistently lower productivity growth after liberalization (Matsuyama (1992)). Thus, selecting the optimal timing of trade liberalization, which allows such infant industries to mature, has significant economic growth implications for policymakers in low-income countries. In this paper, I construct a three-sector model in which the manufacturing sector features spillovers in productivity growth and organizational capital enhancement via technology choice to investigate what the optimal liberalization timing is for low-income countries.

The world has entered another accelerating phase of globalization since the 1990s. International trade has played a more significant role, with the global trade-to-GDP ratio increasing by around 20% from 1990 to 2008, as shown in Figure 1. The advocacy of the Washington Consensus[1] and the establishment of the World Trade Organization (WTO) in 1995 are two major reasons behind this trend. Consequently, many low-income countries chose to join the WTO during the 1990s (see Figure 2). However, the benefits of trade liberalization may have been overestimated, as noted by Shafaeddin (2012). While trade liberalization allows low-income countries to specialize and trade based on their comparative advantages, it also exposes domestic industries without a comparative advantage to severe international competition, which limits their market demand. If these domestic industries have high growth potential, premature liberalization can harm the entire economy. Although such argument applied to any country in the world, I focus on low-income countries in this paper.

This paper focuses on low-income countries because low-income countries typically have a large,

[1] The Washington Consensus, introduced in 1989, advocated for free-market reforms and was promoted by international organizations like the World Bank and the International Monetary Fund during the 1990s.

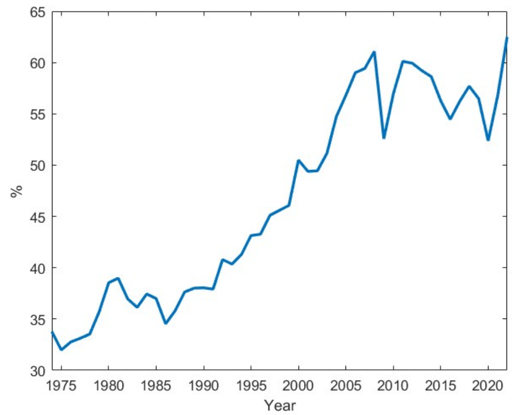

Figure 1: Trade-to-GDP ratio (Global)

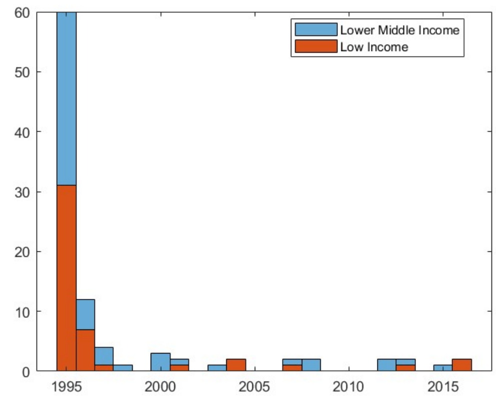

Figure 2: WTO accession year

low-productivity agricultural sector, meaning that they can achieve higher growth simply by reallocating resources from agriculture to other sectors (Herrendorf et al. (2022)). Additionally, sectors other than agriculture are often underdeveloped and lack comparative advantages, making the timing of trade liberalization even more critical, as trade affects the development of tradable sectors. Although reallocating resources from agriculture to both manufacturing and services drives growth, this paper focuses on the transition from agriculture to manufacturing.

The literature has long recognized the unique role of the manufacturing sector. For instance, Duarte and Restuccia (2010) and Rodrik (2013) highlight its growth potential. Inspired by Chandler Jr (1977), I assume that organizational capital is essential for manufacturing production, and manufacturing production, in turn, contributes to the accumulation of such capital. Organizational capital plays a key role in technology adaptation and growth, as suggested by studies such as Atkeson and Kehoe (2005) and Engbom et al. (2024). In this paper, manufacturing firms' operational decisions contribute to the accumulation of organizational capital without knowing it. This learn-by-doing model follows Lucas Jr (1993), which analyzed the economic growth of the Asian Tigers—economies that experienced high growth rates associated with rapid development in manufacturing and large-scale exports of manufactured goods. Once the manufacturing sector becomes strong enough, the country can liberalize trade and further boost economic growth through manufactured exports. However, determining when the manufacturing sector becomes strong enough and understanding the cost of waiting are complex questions.

To address this, I build a three-sector model that incorporates organizational capital within the manufacturing sector. Through manufacturing production, organizational capital is both utilized and accumulated, generating productivity spillovers. However, the full benefit of these productivity spillovers is not captured by firms, creating inefficiencies that incentivize governments to protect the manufacturing sector. On the demand side, non-homothetic preferences in households not only align the model with long-term patterns of structural transformation but also add an additional reason for a low-income country to develop its manufacturing sector. In the model, the government selects the timing of trade liberalization, which allows me to investigate how the reallocation of resources and the development across the agricultural, manufacturing, and service sectors change depending on the comparative advantage of a country has at the moment of liberalization. The model highlights that the time required to rebuild manufacturing production capacity post-liberalization—an often overlooked cost—must be considered when determining the timing of trade liberalization.

To calibrate the model to real-world conditions, I collect data for 77 low-income countries from from World Development Indicator database from World Bank and Penn World Table 10.0 to evaluate their WTO accession decisions. WTO accession is chosen for analysis due to its standardized process[2], the large number of low-income countries that joined the WTO around 1995 (Figure 2), and the potential overestimation of trade liberalization benefits due to the Washington Consensus during the 1990s. In the calibration exercise, I am able to estimate factor intensity parameters and household consumption preferences parameters, which are assumed to be constant across all sample, and calibrate the rest country-specific parameters by targeting the moments like sector employment share, sector expenditure share, and organizational capital growth. The calibration results show that 80.5% (62 out of 77) of the sample countries could improve household welfare by postponing their WTO accession. For these 62 countries, the median difference to optimal timing is 8 years, with a median consumption equivalent variation with optimal liberalization timing is 0.0856%. On the other hand, among these 3 late countries, the median difference to optimal timing is 9 years and the median consumption equivalent variation with optimal liberalization timing is

[2] According to WTO website, the procedure includes the revelation of trade policies, bilateral negotiations with current members, and equal implementation after the negotiation, the commitment written in the accession report, and the vote among current members.

0.2290%.

I further conduct three counterfactual experiments, which I fix either i) the growth rate in manufacturing productivity, ii) the entry rate of manufacturing firms, or iii) the growth rate in organizational capital growth, to see how optimal timing of trade liberalization and welfare change. Comparing to the benchmark calibration, the result shows that the constant growth rate in manufacturing productivity allows countries to liberalize trade earlier while the constant growth rate in organizational capital requires countries to liberalize trade later. The effect on optimal liberalization timing is ambiguous in the constant entry rate case. Finally, I ask how the industrial policy affects welfare in 3 late countries. I find that by replicating the manufacturing value-added path, 2 of 3 countries decrease household's welfare about 4.5% (measured by consumption equivalent variation) while only 1 country increases household's welfare about 8.7%, suggesting that, in this model, industrial policy does not always yield positive results.

The main takeaway of this paper is that the majority of low-income countries accessed WTO too early, leading to a slower accumulation of organizational capital which deters manufacturing firms' entry and technology adoption. Consequently, the productivity growth is lower, which hurts households. The argument is similar to infant industry protection, e.g. Melitz (2005), but this paper is different in twofold. First, an early liberalization weakens the spillover in productivity growth instead of eliminating the whole industry. Second, an industrial policy, e.g. subsidy, strengthens the spillover in the infant industry literature but strength of spillover is limited by the available organizational capital stock in this paper, which implies building up a strong manufacturing sector takes time even when organizational capital is fully utilized.

1.1 Literature Review

This paper is closely related to the literature on structural transformation, international trade, and organizational capital. First, the large-scale reallocation of production factors across sectors as an economy develops is a well-documented phenomenon known as structural transformation (see Kuznets (1973), Maddison (1980), Echevarria (1997)). The literature includes both a supply-side story (relative price) and a demand-side story (income elasticity), which are discussed in detail by Herrendorf et al. (2014). On the supply side, structural transformation is driven by relative price effects due to differing growth rates in sector-specific productivity, as highlighted by Baumol (1967), Ngai and Pissarides (2007), and Acemoglu and Guerrieri (2008). Meanwhile, the demand-side story focuses on non-homothetic preferences, where the composition of consumption drives the allocation of production factors across sectors. Examples include Kongsamut et al. (2001), Matsuyama (2019), Comin et al. (2021), and Alder et al. (2022) who illustrate how income elasticity influences structural transformation. Rather than studying why structural transformation happens, this paper explores how governments can improve household welfare by determining the optimal timing of trade liberalization in an economy with productivity spillovers in the manufacturing sector.

Most of the literature on structural transformation assumes a closed economy setting, but this assumption does not reflect reality. As transportation costs decrease and trade barriers are removed, international trade becomes less costly, and the world becomes more interconnected, as shown in Figure 1. More importantly, international trade breaks the link between domestic supply and domestic demand, allowing trade flows to influence structural transformation. This is particularly true for highly trade-dependent small economies. Matsuyama (1992) shows that a positive agricultural productivity shock has different results for a small economy, depending on whether the country engages in international trade. In reality, Uy et al. (2013) and Erten and Leight (2021) document how exports of manufactured goods accelerate structural transformation. What these papers do not emphasize is the potential drawbacks of liberalization (as pointed out by Shafaeddin (2012) and McMillan et al. (2014)) and the possibility that international trade might slow or even reverse the path of structural transformation if a country has a comparative advantage in the agricultural sector. Therefore, this paper integrates trade liberalization as a government policy tool and proposes an optimal timing after considering all potential growth paths. Conceptually, this paper is closest to Wong and Yip (2010) but this paper differs by adding a service sector and fitting the model better to real data and also incorporates organizational capital to capture learning-by-doing productivity growth. Ravikumar et al. (2024) finds the asymmetric welfare change in between liberalization and protectionism as household can coast on capital stock when trade cost increases suddenly. While this paper has policy choice between protectionism and liberalization, I focus on picking a optimal transitional path from a given initial state instead of studying the transition between two steady states.

The literature has a long tradition of arguing that the modern sector contributes more to economic development than the traditional sector. Lewis (1954) is one such example. The manufacturing sector, often regarded as the core of the modern sector, is considered to generate positive productivity spillovers (e.g., Backus et al. (1992), Duarte and Restuccia (2010), Rodrik (2013), Herrendorf et al. (2022)). Studies have identified human capital as a key factor behind productivity growth and spillovers (e.g., Nelson and Phelps (1966), Lucas Jr (1988), and Benhabib and Spiegel (1994)). Although human capital includes many dimensions, this paper specifically highlights organizational capital or managerial skills (e.g., Samaniego (2006), Beaudry and Francois (2010), Bai et al. (2020), Engbom et al. (2024)) to capture the learning process in manufacturing production. Chandler Jr (1977) emphasizes that the transition to managerial capitalism, which relied heavily on managerial skills/organizational capital, played a crucial role in the economic history of the United States.

The remainder of the paper is organized as follows. Section 2 presents empirical evidence that further motivates this study. Section 3 demonstrates a simple three-sector model with organizational capital and defines the equilibrium in both a closed economy and a small open economy. Section 4 considers a numerical example that illustrates the pros and cons of trade liberalization from a small country government's point of view. I calibrate the model to assess the timing of WTO accession of 77 low-income countries and do counterfactual exercises in Section 5. Section 6 concludes. All derivations and proofs are moved to the Appendix.

2 Empirical Findings

This section presents empirical findings that further motivate this study. Using the employment share and the value-added share across three sectors, I document the importance of the manufacturing sector and the timing of WTO accession to aggregate economic growth and the path of structural transformation. We begin this section by describing the data and then present empirical results.

2.1 Datasets

The empirical analysis employs the number of workers in three sectors from the International Labor Organization (ILO), common macroeconomic variables such as value-added and real GDP per capita from World Development Indicators (WDI), and the Human Development Index from United Nations (UNHDI). The data are yearly data and range from 1991 to 2022. Since I focus on low-income countries, I select countries that were defined as a low-income or lower middle-income country by the World Bank in 1991.[3] The year of WTO accession comes from the WTO website.

2.2 Comparative advantage, and structural transformation

As Herrendorf et al. (2022) points out, a low-income country with a large agricultural sector can narrow the aggregate productivity gap between itself and developed countries simply by reallocating resources from the agricultural sector to other sectors. In addition, international trade facilitates specialization across countries and allows the sector with comparative advantage naturally to attract more resources, which helps a country reallocate resources outside the agricultural sector if the country has comparative advantage in the manufacturing sector. At the same time, organizational capital is crucial for the development in the manufacturing sector, as an insufficient stock of organizational capital slows down the transition.

Following my argument, one should expect that a country would have a faster transition from agricultural sector to manufacturing sector when it has enough organizational capital and a comparative advantage in manufacturing production at the moment of liberalization. We examine how the timing of trade liberalization, organizational capital stock, and comparative advantage in manufacturing production help a country accelerate the reallocation of production factors from the agricultural sector to other sectors by running the following regression.

$$\begin{aligned} \triangle \ell_{ant} =& \beta_0 + \beta_1 L_{ant-1} + \beta_2 y_{nt} + \beta_3 WTO_{nt} + \beta_4 G1_n + \beta_5 G2_n + \\ & \beta_6 OCI_{nt} + \beta_7 RLP_{nt} + \beta_n country + \varepsilon_{nt} \end{aligned} \tag{1}$$

which $\triangle \ell_{ant} = \ell_{ant} - \ell_{ant-1}$ is the change in agricultural employment share, n represents country. The control variables are the log of agricultural workers in the last year (L_{ant-1}), the log of real

[3]The low income to lower middle income countries in 1991 according to World Bank's definition has 118 countries. However, due to data availability, I keep 109 of 118 countries as my sample.

GDP per capita y_{nt}, the dummy variables of being a WTO member in year t (WTO_{nt}), before 2002 ($G1_n$), after 2002 ($G2_n$),[4] high labor productivity in manufacturing production relative to agricultural production (RLP_n),[5] the log of organizational capital index (OCI_{nt})[6], and country fixed effect. We are interested in whether being a WTO member or having a comparative advantage in manufacturing production just before joining the WTO or having a higher human capital stock, which is a proxy for organizational capital stock, speeds up the reduction in agricultural labor share. That is, whether β_3, β_6, β_7 are negative and statistically significant from the regression (1). The result supports my argument, and the following table presents the estimation and p-value for the t-test.

	L_{ant-1}	y_{nt}	WTO_{nt}	$G1_n$	$G2_n$	OCI_{nt}	RLP_n
β	-0.014	0.107	-0.216	0.376	0.102	-0.415	-0.257
p-value	0.169	0.003	0.000	0.000	0.239	0.000	0.000
country	109	obs.	3301	Adj. R^2	0.025		

Table 1: Change in agricultural labor share

Notice that what Table 1 suggests is that WTO accession helps a low-income country to reallocate labor out of agricultural sector faster if she does it after 2002. Meanwhile, having a higher level of organizational capital or a relatively higher labor productivity in manufacturing production one year before becoming a WTO member speeds up the reallocation process.

[4]China joined WTO in 2001. Our paper argues that adopting a delayed liberalization allows a country to build a stronger manufacturing sector, enabling a faster reallocation of workers out of agriculture once trade is liberalized. By using 2002 as a threshold, I categorize China as the early open group, which gives me a more conservative result. In the sample, 82 joined the WTO before 2002, 16 countries joined the WTO after 2002 and 13 have not joined the WTO before 2022.

[5]The labor productivity is defined as sector value-added divided by sector employment. We use the median value from the rest of the world in the year before the studied country joined the WTO as the threshold. If the studied country has a relative labor productivity higher than the median value across the world in the year before joining the WTO, then $RLP_n = 1$, otherwise $RLP_n = 0$. This is a dummy variable that captures comparative advantage in manufacturing production.

[6]Here I use the Human Development Index (HDI) from United Nations with some modifications. The HDI is composed of three sub-indexes including education, life expectancy, and income. However, since I already have real GDP as my control variable, I take the geometric mean of education index and life expectancy index as a country's proxy measurement for organizational capital stock.

2.3 Sectoral productivity and aggregate growth

The resource reallocation out of agricultural sector could be bad if the agricultural sector contributes the most among all sectors in terms of economic growth. However, it is not true as Duarte and Restuccia (2010) and Herrendorf et al. (2022) point out. Here, I verify whether being a member of WTO, having a higher organizational capital stock helps economy grow faster, and which sector contributes more in terms of economic growth by running the following regression.

$$\begin{aligned}\triangle y_{nt} =&\beta_0 + \beta_1 y_{nt-1} + \beta_2 WTO_{nt} + \beta_3 WTOG1_n + \beta_4 WTOG2_n + \beta_5 LP_{ant} + \beta_6 LP_{mnt} + \\ &\beta_7 LP_{snt} + \beta_8 OCI_{nt} + \beta_n country + \varepsilon_{nt} \end{aligned} \tag{2}$$

which $\triangle y_{nt} = y_{nt} - y_{nt-1}$ is the change in real log GDP per capita, and Lp_{int} is log of labor productivity in sector i. Following my argument, I expect β_2, β_5, β_6, β_7, β_8 to be positive and statistically significant from regression (2). In addition, β_5 should be smaller than β_6 and β_7. The result supports my argument, and the following table presents the estimation and p-value for the t-test.

	y_{nt-1}	WTO_{nt}	$G1_n$	$G2_n$	LP_{ant}	LP_{mnt}	LP_{snt}	OCI_{nt}
β	-19.047	1.481	0.629	1.576	4.614	7.229	7.147	9.977
p-value	0.000	0.000	0.782	0.588	0.000	0.000	0.000	0.000
country	108	obs.	3040	Adj. R^2	0.244			

Table 2: Growth Regression

Table 2 implies that becoming a WTO member and having a higher stock of human capital help a low-income country grow faster. In addition, the agricultural sector contributes the least and the manufacturing sector contributes the most to aggregate growth. In fact, if I compare the average real GDP per capita growth rate four years after a country's WTO accession to the growth rate four years before a country's WTO accession, I find that it has a significant positive correlation with worker inflow into the manufacturing sector (Figure 3).[7]

[7] If I conduct the regression on service sector, the coefficient is 0.92 with p-value around 9 percent, which is less significant economically and statistically.

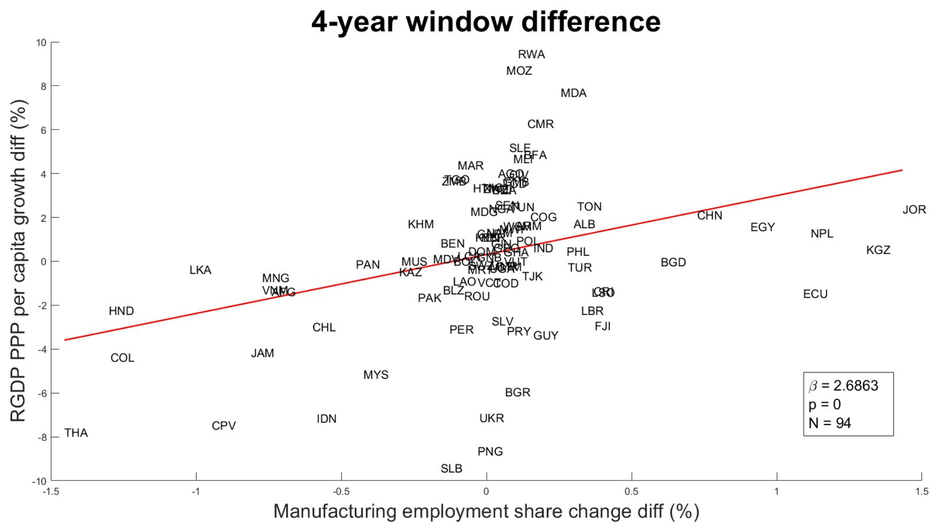

Figure 3: RGDP growth over manufacturing employment share growth

The evidence presented in Table 1 highlights that the timing of trade liberalization affects a country's speed and direction of reallocation of production resources, and the evidence presented in Table 2 and Figure 3 indicate that a low-income country can achieve higher economic growth if it reallocates the production resource from the agricultural sector to other sectors, especially the manufacturing sector. Based on these empirical findings, I build a three-sector model with organizational capital to investigate what the optimal timing is for a low-income country.

3 Model

The model is closely related to Matsuyama (2019) and Comin et al. (2021). We first analyze the model in a closed economy setting and then extend it to a small open economy. In a closed economy, there are L units of households that supply one unit of labor inelastically every period. The size of household remains constant. In the following, I denote the variables per household or per firm in lowercase, while the uppercase represents variables in aggregate level. Each household has a technology to combine sectoral goods from three sectors (agricultural, a, manufacturing, m, service, s) into final goods y_t according to the following equation.

$$\sum_{i\in\{a,m,s\}} \omega_{ci}^{\frac{1}{\sigma_c}} \left(\frac{c_{it}}{y_t^{\varepsilon_i}}\right)^{\frac{\sigma_c-1}{\sigma_c}} = 1;\ \sigma_c \in (0,1),\ \varepsilon_i > 0\ ,\omega_{ci} > 0\ , \tag{3}$$

where c_{it} represents the consumption in sector i at period t, $\varepsilon_i > 0$ is the income elasticity parameter for sector i, and $\omega_{ci} > 0$ is the demand shifter.

As shown in Comin et al. (2021), this preference setting can separate income elasticity from price elasticity. We impose the following restrictions on the preference parameters.

Assumption 1. *Assume that $\varepsilon_s > \varepsilon_m > \varepsilon_a > 0$.*

The Assumption 1, $\varepsilon_s > \varepsilon_m > \varepsilon_a > 0$, captures Engle's Law, which suggests that households consume more service (manufactured) goods relative to manufactured (agricultural) goods as their income increases. Later, I provide empirical evidence supporting Assumption 1 in Section 5.

For the production side, the agricultural sector and the service sector are simplified. There is a representative firm in the agricultural and service sector respectively. Both firms produce sectoral goods by operating a decreasing return to scale technology with capital and labor. The production function for firm in agricultural and service sector is characterized by

$$Y_i = A_{it} K_{it}^{\alpha_{Ki}} L_{it}^{\alpha_{Li}},\ \alpha_{Ki} > 0,\ \alpha_{Li} > 0, \quad \alpha_{Hi} = 1 - \alpha_{Ki} - \alpha_{Li} > 0,\ \ i \in \{a, s\}. \tag{4}$$

The sector-specific productivity grows at a constant rate, i.e. $\frac{A_{it}}{A_{it-1}} = 1 + g_i > 1$ for $i \in \{a, s\}$ for all t.

For the manufacturing sector, there are heterogeneous firms. Each firm is denoted by j and has the same functional form in production function, which is

$$y_{mj} = A_{mjt}^{\xi} K_{mjt}^{\alpha_{Km}} L_{mjt}^{\alpha_{Lm}},\ \alpha_{Km} > 0,\ \alpha_{Lm} > 0, \quad \alpha_{Hm} = 1 - \alpha_{Km} - \alpha_{Lm} > 0. \tag{5}$$

The productivity of each firm has two components. The first component is the **base productivity**, which is the same across all manufacturing firms and is denoted as $\overline{A}_{mt}$. The second component is firm-specific productivity, indicated as η_j, and is a random draw from a Pareto distribution $g(\eta) = \rho\eta^{-(\rho+1)}$ for each period. To make the production function well-defined, I impose the following assumption, which will be used in the proof of Lemma 3.

Assumption 2. *Assume that* $\rho > \frac{1}{\alpha_{Hm}}$.

For each manufacturing firm owner, he needs to choose among three operation options. The three options are: no operation ($\xi = n$), which he decides not to operate; basic level of operation ($\xi = b$), which he pays ϕ_t to employ one unit of organizational capital (H) to produce with productivity $A^b_{mjt} = \overline{A}_{mt}\eta_j$; advanced level of operation ($\xi = b$), which he pays $2\phi_t$ to employ two units of organizational capital to produce with productivity $A^a_{mjt} = \overline{A}_{mt}(1+\nu)^{\alpha_{Hm}}\eta_j$. The parameter $\nu > 0$ is the productivity gain by choosing an advanced level of operation. The rent of employing organizational capital, ϕ_t, is in terms of manufactured goods and will be redistributed back to the household. Finally, I have the following assumption for the organizational capital rental rate.

Assumption 3. *Assume that* $\phi \geq \underline{\phi}$.

Assumption 3 means the rent of employing organizational capital, ϕ_t, needs to be larger than a certain threshold, $\underline{\phi}$, to successfully rent organizational capital. We interpret $\underline{\phi}$ as the reserved wage for managers. Being a manager requires extra effort and knowledge. Such requirements allow managers to charge a higher wage. When the salary is not enough to compensate for the effort, he can always choose to work as a normal worker. The following table summarizes the differences in productivity and cost between levels of operation.

Level of operation (ξ)	Productivity (A^{ξ}_{mjt})	Organizational Capital (H_t)	Rent
No operation (n)	0	0	0
Basic operation (b)	$A_{mt}\eta_j$	1	ϕ_t
Advanced operation (a)	$A_{mt}(1+\nu)^{\alpha_{Hm}}\eta_j$	2	$2\phi_t$

Table 3: Manufacturing firm operation choice

At the beginning of each period, there are N new entrant firms that are born and draw firm-specific productivity together with the survival firms' owners. After the firm-specific productivity is realized, each firm owner takes the prices as given and makes the operation choice to maximize profit. If he chooses no operation, then the firm goes bankrupt. Therefore, only the fraction $1-G(\eta_{nt})$ survives until the next period, and η_{nt} is the **entry threshold**, which indicates the lowest firm's specific productivity among firms that earn positive profit. The evolution of manufacturing firms is

$$N_{t+1} = N_{pt}[1 - G(\eta_{nt})] = (N_t + N)[1 - G(\eta_{nt})], \tag{6}$$

which N_{pt} is the total number of firms before the realization of firm's specific productivity.

The organizational capital H_t^s, which the superscript s represents the supply, and the physical capital K_t are owned by the households. The former is accumulated by the manufacturing firm's operation decision, while the latter is accumulated through household savings. In each period, the survival firms contribute to the organizational capital accumulation and the evolution of organizational capital is

$$H_{t+1}^s = (1 - \delta_H)H_t^s + \triangle H_t = (1 - \delta_H)H_t^s + \gamma_H \int_{\eta_{nt}}^{\infty} \eta dG(\eta) N_{pt} = (1 - \delta_H)H_t^s + \frac{\gamma_H \rho}{\rho - 1}\eta_{nt}^{1-\rho} N_{pt} \tag{7}$$

which δ_H is the depreciation rate in organizational capital. Because manufacturing firms, both survival firms and newborns, are renters of organizational capital, the relative supply of organizational capital is defined as $h_t^s = \frac{H_t^s}{N_{pt}}$. Combining (6) and (7), the evolution of relative supply of organizational capital is

$$h_{t+1}^s = \frac{N_{pt}}{N_{pt+1}} \left[(1 - \delta_H)h_t^s + \frac{\gamma_H \rho}{\rho - 1}\eta_{nt}^{1-\rho}\right] = \frac{(1 - \delta_H)h_t^s + \frac{\gamma_H \rho}{\rho-1}\eta_{nt}^{1-\rho}}{1 - \frac{N_t}{N_t + N} + \eta_{nt}^{-\rho}} \tag{8}$$

Meanwhile, the sectoral level productivity evolves according to the following equation.

$$\frac{\overline{A}_{mt+1}}{\overline{A}_{mt}} = 1 + \gamma_A \left(\int_{\eta_{nt}}^{\eta_{at}} \eta dG(\eta) + \int_{\eta_{at}}^{\infty} (1 + \nu)^{\alpha_{Hm}} \eta dG(\eta) \right) + \gamma_T, \ \gamma_A > 0, \ \gamma_T > 0 \tag{9}$$

where η_{at} is the **advanced threshold** indicating the lowest firm-specific productivity among firms choose advanced level of operation, γ_A captures the strength of productivity growth spillover, and γ_T comes from other sources of growth such as international spillover. The growth of sectoral level productivity comes both from basic and advanced operation. The goods market and both capital markets are perfectly competitive while the labor market has friction that allows the agricultural sector to hire workers at a lower wage $W_{at} = \theta W_t$ where $\theta \in (0, 1)$ compared to other sectors.[8] Finally, the profit from all sectors will be evenly distributed to households.

[8] This assumption follows Restuccia et al. (2008). Our conclusion does not depend on this assumption. However, it allows me to better fit the data.

3.1 Household Problem

At period t, the representative household earns the average wage rate, $\overline{W}_t$, capital rent, R_t, by supplying inelastically one unit of labor and capital stock, and shares the rent of organizational capital, $\phi_t h_t$, and the profit from all sectors, π_t. The household decides consumption across sectors to maximize final goods production and allocates final goods to consumption and investment in physical capital. The utility maximization problem is characterized as follows.

$$
\begin{gathered}
\max_{\{c_{it},\, c_t,\, k_{t+1}\}} \sum_{t=0} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma} \\
s.t.\ \overline{W}_t + R_t k_t + \phi_t h_t + \pi_t = e_t = \mathcal{P}_t\, y_t = \mathcal{P}_t(c_t + x_t) \\
\overline{W}_t = \theta \ell_{at} W_t + \ell_{mt} W_t + \ell_{st} W_t,\ \theta \in (0,1) \\
\left\{ e_t = \min_{\{c_{it}\}} \sum_{i\in\{a,m,s\}} p_{it} c_{it}, \quad s.t. \sum_{i\in\{a,m,s\}} \omega_{ci} \left(\frac{c_{it}}{y_t^{\varepsilon_i}} \right)^{\frac{\sigma_c - 1}{\sigma_c}} = 1 \right\} \\
k_{t+1} = (1-\delta_K) k_t + \frac{x_t}{1+\gamma_K}, \quad \gamma_K \geq 0, \quad k_0,\ h_t \text{ are given.}
\end{gathered}
\tag{10}
$$

ℓ_{it} is the sectoral employment share, p_{it} is the price of sectoral goods, e_t is the nominal aggregate expenditure, δ_K is the physical capital depreciation rate, and γ_K is the investment efficiency parameter.[9] Notice that organizational capital rent income and firm's profit are both equilibrium results depending on the firm's decisions, and hence households take them as given.

To derive optimal conditions, I first solve the cost minimization problem in the curly bracket. The optimal demand function for sectoral goods is

$$
c_{it} = \left(\frac{p_{it}}{e_t} \right)^{-\sigma_c} \omega_{ci} y_t^{\varepsilon_i (1-\sigma_c)}. \tag{11}
$$

The expenditure share in sector i is thus

$$
\mu_{it} = \frac{p_{it} c_{it}}{e_t} = \left(\frac{p_{it}}{e_t} \right)^{1-\sigma_c} \omega_{ci} y_t^{\varepsilon_i (1-\sigma_c)}. \tag{12}
$$

The Euler equation is

$$
\left(\frac{c_{t+1}}{c_t} \right)^{\sigma} = \beta \left[\frac{R_{t+1}}{\mathcal{P}_{t+1} \bar{\varepsilon}_{t+1}} + 1 - \delta_K \right] = \beta r_{t+1} \tag{13}
$$

[9]This assumption also follows Restuccia et al. (2008) to capture that investment might be costly in low-income countries. Again, my conclusion does not depend on this assumption. It allows me to fit the data better in the calibration section.

where $\bar{\varepsilon}_{t+1} = \sum_{i\in\{a,m,s\}} \varepsilon_i \mu_{it}$ and $\mathcal{P}_t = \frac{e_t}{y_t} = \left[\sum_{i\in\{a,m,s\}} p_{it}^{1-\sigma_c} \omega_{ci} y_t^{(\varepsilon_i - 1)(1-\sigma_c)}\right]^{\frac{1}{1-\sigma_c}}$ is the aggregate price level.[10]

3.2 Firm Problem

Firms in each sector take factor prices as given and produce sectoral goods with a decreasing return to scale production function $Y_{it} = A_{it} K_{it}^{\alpha_{Ki}} L_{it}^{\alpha_{Li}}$, which $\alpha_{Hi} = 1 - \alpha_{Ki} - \alpha_{Li} \in (0, 1)$, to maximize profit. The profit maximization problem for a firm in sector $i \in \{a,\ s\}$ is characterized by the following.

$$\Pi_{at} = p_{at} Y_{at} - R_t K_{at} - \theta W_t L_{at}, \quad \Pi_{st} = p_{st} Y_{st} - R_t K_{st} - W_t L_{st},\ . \tag{14}$$

The optimal conditions are

$$\frac{\alpha_{Ka}}{\alpha_{La}} = \frac{R_t K_{at}}{\theta W_t L_{at}}; \quad \frac{\alpha_{Ks}}{\alpha_{Ls}} = \frac{R_t K_{st}}{W_t L_{st}}. \tag{15}$$

The corresponding profit is

$$\begin{aligned}
\Pi_{at} &= \alpha_{Ha} p_{at} \left[A_{at} \left(\frac{\alpha_{Ka}}{R_t/p_{at}}\right)^{\alpha_{Ka}} \left(\frac{\alpha_{La}}{\theta W_t/p_{at}}\right)^{\alpha_{La}}\right]^{\frac{1}{\alpha_{Ha}}}, \\
\Pi_{st} &= \alpha_{Hs} p_{st} \left[A_{st} \left(\frac{\alpha_{Ks}}{R_t/p_{st}}\right)^{\alpha_{Ks}} \left(\frac{\alpha_{Ls}}{W_t/p_{st}}\right)^{\alpha_{Ls}}\right]^{\frac{1}{\alpha_{Hs}}}.
\end{aligned}$$

For an individual manufacturing firm, I get optimal conditions by replacing sectoral productivity with individual firm's productivity under a given operation level choice A_{mjt}^{ξ} where $\xi \in \{n,\ b,\ a\}$ stands for no operation, basic level, advanced level. Therefore, a manufacturing firm owner chooses to operation level by maximizing the following profit

$$\xi^* = \arg\max_{\xi\in\{n,\, b,\, a\}} \Pi_{mjt}^{\xi} = \arg\max_{\xi\in\{n,\, b,\, a\}} \pi_{mjt}^{\xi} - p_{mt}(\mathbb{1}_{\xi\neq n} + \mathbb{1}_{\xi=a})\phi_t$$

where

$$\pi_{mjt}^{\xi} = \alpha_{Hm} p_{mt} \left[A_{mjt}^{\xi} \left(\frac{\alpha_{Km}}{R_t/p_{mt}}\right)^{\alpha_{Km}} \left(\frac{\alpha_{Lm}}{W_t/p_{mt}}\right)^{\alpha_{Lm}}\right]^{\frac{1}{\alpha_{Hm}}},\ \xi \in \{n,\ b,\ a\}.$$

To derive the demand for organizational capital, it is convenient to define the operational unit cost $F_t \equiv \left(\frac{R_t/p_{mt}}{\alpha_{Km}}\right)^{\alpha_{Km}} \left(\frac{W_t/p_{mt}}{\alpha_{Lm}}\right)^{\alpha_{Lm}} \left(\frac{1}{\alpha_{Hm}}\right)^{\alpha_{Hm}} / \overline{A}_{mt}$. For a firm with firm's specific productivity η_j, it is profitable to operate in the basic level operation if

$$\pi_{mjt}^{b} \geq p_{mt}\phi_t \Rightarrow \eta_j \geq F_t \phi_t^{\alpha_{Hm}} \equiv \eta_{bt}; \tag{16}$$

[10] For the detailed derivations, please refer to the Appendix.

and it is profitable to operate in the advanced level operation if

$$\pi^a_{mjt} \geq p_{mt} 2\phi_t \Rightarrow \eta_j \geq F_t \left(\frac{2\phi_t}{1+\nu}\right)^{\alpha_{Hm}} \equiv \eta_{a1t}. \tag{17}$$

For a firm with firm's specific productivity η_j, the firm earns more to operate in the advanced level operation than basic level operation if

$$\pi^a_{mjt} - \pi^b_{mjt} \geq p_{mt}\phi_t \Rightarrow \eta_j \geq F_t \left(\frac{\phi_t}{\nu}\right)^{\alpha_{Hm}} \equiv \eta_{a2t}. \tag{18}$$

We denote the minimum firm-specific productivity that a firm's owner can make more positive profit when he operates at the advanced level as $\underline{\eta}_{at}$. Hence, among potential manufacturing firms, the owner of a firm chooses to operate at the advanced level if $\eta_j \geq \underline{\eta}_{at} = \max\{\eta_{a1t},\ \eta_{a2t}\}$. Similarly, I denote the minimum firm-specific productivity that a firm's owner can make a positive profit when he chooses to operate as $\underline{\eta}_{nt}$. Thereby, a firm's owner chooses to operate if $\eta_j \geq \underline{\eta}_{nt} = \min\{\eta_{bt},\ \underline{\eta}_{at}\}$. The relationship between $\underline{\eta}_{at}$ and $\underline{\eta}_{nt}$ is summarized in the following Lemma.

Lemma 1. *For any given F_t, if $\nu \geq 1$, then $\underline{\eta}_{nt} = \underline{\eta}_{at}$, which means that all the owners of the firm with $\eta_j \geq \underline{\eta}_{nt} = \underline{\eta}_{at}$ choose to operate at the advanced level and choose no operation if $\eta_j < \underline{\eta}_{nt}$. If $\nu \in (0,1)$, then $\underline{\eta}_{nt} = \eta_{bt} < \underline{\eta}_{at}$, which means that all the owners of the firm choose to operate at the advanced level if $\eta_j \geq \underline{\eta}_{at}$, choose to operate at the basic level if $\eta_j \in [\underline{\eta}_{nt},\ \underline{\eta}_{at})$, and choose no operation if $\eta_j < \underline{\eta}_{nt}$.*

The intuition behind Lemma 1 is that it is more likely that every firm that chooses to operate would operate at the advanced level since the productivity gain is large, i.e. $\nu \to 1$. Conversely, if the productivity gain is small, then only those firms with firm-specific productivity high enough would choose to operate at the advanced level. Based on the observation of Lemma 1, I limit my focus to a more complex case $\nu \in (0,1)$ for the rest of this paper. Also note that $\eta_j \in [1,\infty)$ and hence the entry threshold η_{nt} and advanced threshold η_{at} are

$$\eta_{nt} = \max\{\underline{\eta}_{nt}, 1\}, \qquad \eta_{at} = \max\{\underline{\eta}_{at}, 1\}, \tag{19}$$

Given $\nu < 1$, the demand of organizational capital is

$$H^d_t = [1 - G(\eta_{nt}) + 1 - G(\eta_{at})]N_{pt}. \tag{20}$$

We define the relative demand of organizational capital as the demand of organizational capital per potential firm, which is

$$h_t^d = \frac{H_t^d}{N_{pt}} = 1 - G(\eta_{nt}) + 1 - G(\eta_{at}) = \eta_{nt}^{-\rho} + \eta_{at}^{-\rho} \tag{21}$$

If $\eta_{nt} > 1$ in the equilibrium, then equation (21) can be further written as $h_t^d = \frac{1+\nu^{\rho\alpha_{Hm}}}{(F_t\phi_t^{\alpha_{Hm}})^\rho}$ after substituting equation (16) and (17). In such scenario, the demand is higher if ν is larger or F_t is smaller for a given rental price ϕ_t. The former means the gain from choosing advanced level of operation becomes larger, and the latter implies the operative unit cost becomes smaller. Both raise firm's profit and boost the demand of organizational capital at a given organizational capital rent ϕ_t. There are two possible outcomes for organizational capital market in equilibrium, which is summarized in the following Lemma.

Lemma 2. *Suppose the relative organizational capital supply $h_t^s \leq 2$. There exists a threshold $\underline{F}_t$ such that $h_t^d(\underline{F}_t, \underline{\phi}) = h_t^s$. If $F_t \leq \underline{F}_t$, then all organizational capital will be utilized $h_t^d = h_t^s$ and the rental price is higher than the minimum requirement $\phi_t \geq \underline{\phi}$. If $F_t > \underline{F}_t$, then the only part of organizational capital will be utilized, $h_t^d < h_t^s$, the rental price equals the minimum requirement $\phi_t = \underline{\phi}$.*

We have not imposed any restriction on the law of motion of the relative organizational capital supply, which means h_t^s could be unbounded above. However, the maximum organizational capital demand is 2 units per firm by construction, and thus I focus on $h_t^s \leq 2$ in Lemma 2. The intuition of Lemma 2 is that if the demand for manufactured goods becomes weaker, which implies a higher F_t, then more firms are idle because running a business is not profitable. Therefore, in this model, there might exist some organizational capital left unused from period to period.

Furthermore, in each period, if $F_t \leq \underline{F}_t$, then there exists a quantity quality trade-off. Since the supply of organizational capital and the number of potential firms are fixed at the beginning of each period, more firms operate at the advanced level means that less firms choose to operate. For example, suppose that there is an one-period increase in ν, which reduces the advanced threshold and leads to a higher demand for organizational capital. But the supply of organizational capital is fixed and no idle organizational capital is left. The result is that the higher demand drives up the rent and makes it difficult for low-productivity firms to earn a profit, which raises the entry threshold.

To define the equilibrium, it is convenient to define the production capacity for the whole manufacturing sector in the following lemma.

Lemma 3. *Given factor prices and operation choices across all firm, the production capacity for the whole manufacturing sector is*

$$A_{mt} = \overline{A}_{mt} \left\{ \frac{\alpha_{Hm}\rho}{\alpha_{Hm}\rho - 1} \left[(\eta_{nt})^{\frac{1}{\alpha_{Hm}} - \rho} + \nu \, (\eta_{at})^{\frac{1}{\alpha_{Hm}} - \rho} \right] N_{pt} \right\}^{\alpha_{Hm}} \tag{22}$$

and the aggregate output for manufacturing sector is

$$Y_{mt} = \int_1^\infty y_{mjt} dG(\eta) N_{pt} = \left[A_{mt} \left(\frac{\alpha_{Km}}{R_t/p_{mt}} \right)^{\alpha_{Km}} \left(\frac{\alpha_{Lm}}{W_t/p_{mt}} \right)^{\alpha_{Lm}} \right]^{\frac{1}{\alpha_{Hm}}}$$

and factor demand for manufacturing sector is

$$K_{mt} = \int_1^\infty K_{mjt} dG(\eta) N_{pt} = \left[A_{mt} \left(\frac{\alpha_{Km}}{R_t/p_{mt}} \right)^{1-\alpha_{Lm}} \left(\frac{\alpha_{Lm}}{W_t/p_{mt}} \right)^{\alpha_{Lm}} \right]^{\frac{1}{\alpha_{Hm}}},$$

$$L_{mt} = \int_1^\infty L_{mjt} dG(\eta) N_{pt} = \left[A_{mt} \left(\frac{\alpha_{Km}}{R_t/p_{mt}} \right)^{\alpha_{Km}} \left(\frac{\alpha_{Lm}}{W_t/p_{mt}} \right)^{1-\alpha_{Km}} \right]^{\frac{1}{\alpha_{Hm}}}.$$

The manufacturing production capacity (22) is affected by the evolution of manufacturing base productivity ($\overline{A}_{mt}$), the firm's operation threshold ($\eta_{nt}, \ \eta_{at}$), and the potential number of firms (N_{pt}). All of these three factors are related to organizational capital. In one extreme, if the organizational capital stock is zero, then there will be no entry, and the manufacturing production capacity becomes zero. Meanwhile, the growth of manufacturing production capacity depends on the growth of organizational capital stock because a slower growth in organizational capital stock leads to a slower growth in the potential number of firms and a slower reduction in the firm's operation threshold. The dynamic is summarized in the following Proposition.

Proposition 1. *Given that Assumption 2 holds, the manufacturing production capacity, A_{mt}, decreases in the operation thresholds η_{nt} and η_{at} and increases $\overline{A}_{mt}$ and N_{pt}. Furthermore, if the operative cost $F_t < \underline{F}_t$, then the entry threshold (η_{nt}) or advanced threshold (η_{at}) decrease in h_t^s.*

Note that there is no extra cost of withdrawing from the market for manufacturing firms. However, organizational capital is required to start a firm, and the number of newborn firms is fixed. Such an asymmetry leads to a prolonged recovery of the manufacturing production capacity loss caused by a massive withdrawal.

Corollary 1. *The loss in manufacturing production capacity due to massive withdrawal of firms occurs instantly and recovery takes longer time if newborn firms (N) are rare, the reserved rent for organizational capital $\underline{\phi}$ is high, or the growth of organizational capital, h_t^s, is slow.*

3.3 Equilibrium

We now define equilibrium in a closed economy and extend it to a small open economy framework later. In equilibrium, the goods market clearing is satisfied in each sector and the firm's profit is redistributed to the household.

$$Lc_{it} = Y_{it},\ \forall i \in \{a, m, s\}; \quad \pi_t = \frac{\Pi_{at} + \int_1^\infty \Pi_{mjt}^{\xi^*} dG(\eta) + \Pi_{st}}{L}. \tag{23}$$

The labor and physical capital market clearing conditions are satisfied.

$$\sum_{i\in\{a,m,s\}} L_{it} = L; \quad \sum_{i\in\{a,m,s\}} K_{it} = K_t. \tag{24}$$

The demand in organizational capital market is satisfied.

$$h_t^d \le h_t^s. \tag{25}$$

The equilibrium is defined in the following.

Definition 1. *The allocation $\{c_{it}, c_t, x_t, L_{it}, K_{it}, h_t^d\}$ and the operation threshold $\{\eta_{nt}, \eta_{at}\}$ satisfy the following conditions given the prices $\{p_{it}, W_t, R_t, \phi_t\}$ and the sequence $\{K_t,\ h_t^s,\ A_{at},\ \overline{A}_{mt},\ A_{st}\}$*

- *Household's optimal conditions (11) for all sectors and Euler equation (13);*
- *Firm's optimal conditions (15) for all sectors;*
- *Operation decision for manufacturing firm is chosen optimally;*
- *Goods market clearing conditions (23) for all sectors;*

- *Labor market and physical capital market clearing conditions (24);*
- *Organizational capital demand (25) is satisfied and $\phi_t \geq \underline{\phi}$ for all t;*
- *Laws of motion (6) - (9) are satisfied.*

Now I extend this framework to a small open economy. The prices of tradable goods, which are $\{p_{at}, p_{mt}\}$, are determined by the rest of the world $\{p^w_{at}, p^w_{mt}\}$. We assume that the small economy remains financial autarky and thus the trade must be balanced. The firms take the prices and factor prices as given and hence the optimal factor demand still follows (15). The rest of optimal conditions remains unchanged except for goods market clearing conditions in agricultural and manufacturing sector are replaced with one balanced trade condition for each period, which is

$$p^w_{at}(Y_{at} - Lc_{at}) + p^w_{mt}(Y_{mt} - Lc_{mt}) = 0, \tag{26}$$

which replaces the original goods market clearing conditions in agricultural and manufacturing sector. The definition of equilibrium in a small open economy is modified as follows.

Definition 2. *The allocation $\{c_{it}, c_t, x_t, L_{it}, K_{it}, h^d_t\}$ and the operation threshold $\{\eta_{nt}, \eta_{at}\}$ satisfy the following conditions given the prices $\{p^w_{at}, p^w_{mt}, p_{st}, W_t, R_t, \phi_t\}$ and the sequence*
$\{K_t,\ h^s_t,\ A_{at},\ \overline{A}_{mt},\ A_{st}\}$

- *Household's optimal conditions (11) for all sectors and Euler equation (13);*
- *Firm's optimal conditions (15) for all sectors;*
- *Operation decision for manufacturing firm is chosen optimally;*
- *Service goods market clearing condition (23) and balanced trade condition (26) are satisfied;*
- *Labor market and physical capital market clearing conditions (24);*
- *Organizational capital demand (25) is satisfied and $\phi_t \geq \underline{\phi}$ for all t;*
- *Laws of motion (6) - (9) are satisfied.*

Since service goods are non-tradable, the price ratio of agricultural goods and manufactured goods determined the trade flow as summarized below.

Proposition 2. *If the price ratio of agricultural goods and manufactured goods in the closed economy equilibrium* $\frac{p^c_{mt}}{p^c_{at}}$ *is smaller than the price ratio of the world price* $\frac{p^w_{mt}}{p^w_{at}}$*, then the small economy exports manufactured goods and imports agricultural goods in the small open economy equilibrium. Vice versa.*

3.4 The evolution of h^s_t

In this section, I investigate how h^s_t evolves in an equilibrium path. We rewrite equation (8) as follows.

$$\frac{h^s_{t+1}}{h^s_t} = \frac{1-\delta_H + \gamma_H \frac{\rho}{\rho-1}\eta_{nt}^{1-\rho}(h^s_t)^{-1}}{1-\frac{N_t}{N_t+N}+\eta_{nt}^{-\rho}} \tag{27}$$

which implies that

$$\begin{aligned} & \frac{h^s_{t+1}}{h^s_t} \gtreqless 1 \\ \Leftrightarrow \quad & \gamma_H \frac{\rho}{\rho-1}\eta_{nt}^{1-\rho}(h^s_t)^{-1} - \delta_H \gtreqless \eta_{nt}^{-\rho} - \frac{N_t}{N_t+N} \\ \Leftrightarrow \quad & \gamma_H \frac{\rho}{\rho-1}\eta_{nt}(h^s_t)^{-1} + \left(\frac{N_t}{N_t+N} - \delta_H\right)\eta_{nt}^{\rho} - 1 \gtreqless 0. \end{aligned}$$

We thereby have the following Proposition that shows the conditions for h^s_t to grow.

Proposition 3. *For any given* h^s_t *and* N_t*, I define*

$$Q(\eta_{nt}) = \gamma_H \frac{\rho}{\rho-1}\eta_{nt}(h^s_t)^{-1} + \left(\frac{N_t}{N_t+N} - \delta_H\right)\eta_{nt}^{\rho} - 1, \quad \eta_{nt} \in [1, \infty).$$

There will be four cases. In each case, certain conditions have to be satisfied for h^s_t *to grow. Here are the conditions.*

- *Case 1 (*$Q(1) \geq 0$ *and* $\frac{N_t}{N_t+N} \geq \delta_H$*):* $\frac{h^s_{t+1}}{h^s_t} \geq 1$ *if and only if* $\eta_{nt} \in [1, \infty)$*;*
- *Case 2 (*$Q(1) < 0$ *and* $\frac{N_t}{N_t+N} \geq \delta_H$*):* $\frac{h^s_{t+1}}{h^s_t} \geq 1$ *if and only if* $\eta_{nt} \in [\eta_2^\dagger, \infty)$*;*
- *Case 3 (*$Q(1) \geq 0$ *and* $\frac{N_t}{N_t+N} < \delta_H$*):* $\frac{h^s_{t+1}}{h^s_t} \geq 1$ *if and only if* $\eta_{nt} \in [1, \eta_3^\dagger]$*.*

There are four sub-cases for Case 4, which is the case for $Q(1) < 0$ *and* $\frac{N_t}{N_t+N} < \delta_H$*. We first denote* $\widehat{\eta} = \left[\frac{\gamma_H}{(\rho-1)h^s_t}\left(\delta_H - \frac{N_t}{N_t+N}\right)^{-1}\right]^{\frac{1}{\rho-1}}$*. The following are the conditions for* h^s_t *to grow in Case 4.*

- *Case 4-1 ($\widehat{\eta} \leq 1$): $\frac{h_{t+1}^s}{h_t^s} < 1$ for all $\eta_{nt} \in [1, \infty)$, which means it will certainly decrease.*
- *Case 4-2 ($\widehat{\eta} > 1$ and $Q(\widehat{\eta}) > 0$): $\frac{h_{t+1}^s}{h_t^s} \geq 1$ if and only if $\eta_{nt} \in [\eta_4^\dagger, \eta_5^\dagger]$;*
- *Case 4-3 ($\widehat{\eta} > 1$ and $Q(\widehat{\eta}) = 0$): $\frac{h_{t+1}^s}{h_t^s} = 1$ if and only if $\eta_{nt} = \widehat{\eta}$;*
- *Case 4-4 ($\widehat{\eta} > 1$ and $Q(\widehat{\eta}) < 0$): $\frac{h_{t+1}^s}{h_t^s} < 1$ for all $\eta_{nt} \in [1, \infty)$, which means it will certainly decrease.*

For a given price sequence, there will be three possible types of steady state for variables $\{H_t^s,\ N_t,\ h_t^s\}$, which feature N_t approach one of $\left\{\infty,\ \overline{N} \in (0, \infty),\ 0\right\}$ in the long run. We examine each case in the following. If $N_t \to \infty$ in the steady state, then it requires $\eta_{nt} = 1$ in the steady state. This implies that equation (27) becomes $\frac{h_{t+1}^s}{h_t^s} = 1 - \delta_H + \gamma_H \frac{\rho}{\rho-1}(h_t^s)^{-1}$. If $h_t^s \to \infty$ then $\frac{h_{t+1}^s}{h_t^s} = 1 - \delta_H < 1$ in the steady state that accompanies $h_t^s \to 0$ and there exists a contradiction. Therefore, $h_t^s \to \overline{h}^s \in (0, \infty)$, which implies that $\overline{h}^s = \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}$ makes $\frac{h_{t+1}^s}{h_t^s} \to 1$ stable, and the organizational capital stock converges to $H_t^s \to h_t^s(N_t + N) = \infty$ and grows at the same rate as $(N_t + N)$.

Second, if $N_t \to 0$ is in the steady state, then it requires $\eta_{nt} \to \infty$ in the steady state. This implies $\frac{h_{t+1}^s}{h_t^s} = \frac{H_{t+1}^s}{H_t^s} = 1 - \delta_H < 1$ in steady state. Therefore, the steady state is $\{H_t^s,\ N_t,\ h_t^s\} = \{0,\ 0,\ 0\}$ for all t, which means that the whole manufacturing sector shuts down and that no firm is allowed to operate because there is no organizational capital to use.

Finally, if $N_t \to \overline{N} \in (0, \infty)$ is in steady state, then it requires $\eta_{nt} \to \overline{\eta}_n$ in steady state. This also implies $H_t^s \to \overline{H}^s$ and $h_t^s \to \overline{h}^s$ as well. The following assumption ensures that $\overline{h}^s$ falls below 2.

Assumption 4. *Assume that $1 < \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1} \leq (1 + \nu^{\rho\alpha_{Hm}})$.*

We characterize the steady state for $\{H_t^s,\ N_t,\ h_t^s\}$ in the following Proposition.

Proposition 4. *Given Assumption 4 holds, if $N_t \to \overline{N} \in (0, \infty)$ in the steady state, then*

$$
\begin{aligned}
\eta_{nt} &\to \overline{\eta}_n = (\frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1})^{-1}(1+\nu^{\rho\alpha_{Hm}}) > 1 \\
\eta_{at} &\to \overline{\eta}_a = \overline{\eta}_n \nu^{-\alpha_{Hm}} \\
N_t &\to \overline{N} = \frac{\overline{\eta}_n^{-\rho}}{1-\overline{\eta}_n^{-\rho}} N \\
H_t^s &\to \overline{H}^s = \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}(\overline{N}+N)\overline{\eta}_n^{1-\rho} \\
h_t^s &\to = \overline{h}^s = \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}\overline{\eta}_n^{1-\rho} \in (0,\ 2) \\
F_t \phi_t^{\alpha_{Hm}} &\to = \left[\frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1} - 1\right]^{-1}(1+\nu^{\rho\alpha_{Hm}}).
\end{aligned}
$$

4 Optimal timing for trade liberalization

The key question in this paper is when a small economy should liberalize trade. To formalize this question, I assume that there exists a government in this small economy. The government has knowledge of the world price $\{p_{at}^w,\ p_{mt}^w\}$ and decides the time of trade liberalization at $\hat{t} \in [0, \infty)$, and households and firms do not know the time of trade liberalization beforehand.[11] When the small economy liberalizes trade, the prices of tradable goods are equal to the rest of the world, and the small economy remains open to trade forever. To make this paper more concise, I take agricultural goods as based goods and therefore p_{at} and p_{at}^w equal 1 for all periods and all other prices should be interpreted as the price relative to agricultural goods. Therefore, the government's problem is as follows.

$$
t^* = \max_{\hat{t} \geq 1} \sum_{t=1}^{\infty} \beta^{t-1} u(c_t^{\hat{t}}) \tag{28}
$$

where $c_t^{\hat{t}}$ represents the household consumption at period t (subscript) when the government liberalizes trade at period $\hat{t}$ (superscript). Specifically, $c_t^{\hat{t}}$ satisfies the equilibrium conditions defined in Definition 1 for all $t < \hat{t}$ when the small economy is closed and $c_t^{\hat{t}}$ satisfies the equilibrium conditions

[11] We do not consider tariff and industrial policy in this paper because such active policy tools require the government to have the information to pick the industry with potential. Furthermore, the government needs to commit that such intervention is temporary to achieve the ideal outcome. The government in low-income countries lacks these types of abilities, and most industrial policies are implemented by advanced countries in reality, as documented in Juhász et al. (2023). Therefore, I believe that it is appropriate to limit my attention to the timing of trade liberalization.

defined in Definition 2 for all $t \geq \hat{t}$ when the small economy is open.

The following Proposition states that when "*the sooner, the better*" argument applied to trade liberalization for the small economy.

Proposition 5. *Given the price sequence of the rest of the world $\{p^w_{mt}\}$ and the price sequence of the small closed economy $\{p^c_{mt}\}$ for $t \geq 0$, if the path of $\{\eta_{at}\}$ is the same in closed and liberalization scenarios, then the objective function $\sum\limits_{t=1}^{\infty} \beta^{t-1} u(c_t)$ is maximized if the government liberalizes trade immediately.*

Proposition 5 highlights the fact that if trade liberalization does not discourage firm entry and firm's decision on choosing the advanced operation, then trade liberalization only has benefit and the government should do it as soon as possible. In other words, waiting could be a better option only if instant trade liberalization deters firm entry and firm's decision on advanced operation.

If the discounted utility of instant liberalization is used as the benchmark, then the objective function (28) can be rewritten as

$$t^* = \max_{\hat{t} \geq 2} \sum_{t=1}^{\infty} \beta^{t-1}[u(c^{\hat{t}}_t) - u(c^1_t)] = \max_{\hat{t} \geq 2} \left\{ \sum_{t=1}^{\hat{t}-1} \beta^{t-1}[u(c^{\hat{t}}_t) - u(c^1_t)] + \sum_{t=\hat{t}}^{\infty} \beta^{t-1}[u(c^{\hat{t}}_t) - u(c^1_t)] \right\}. \quad (29)$$

The first term in the curly bracket ($\sum_{t=1}^{\hat{t}-1} \beta^t[u(c^{\hat{t}}_t) - u(c^1_t)]$) represents the gain from trade forgone while the small economy chooses to remain closed. The second term in the curly bracket ($\sum_{t=\hat{t}}^{\infty} \beta^t[u(c^{\hat{t}}_t) - u(c^1_t)]$) captures the positive gain in the future utility stream. We provide the following numerical example to illustrate the model mechanism and optimal timing of trade liberalization. To demonstrate the mechanism as clearly as possible, I remove labor market friction ($\theta = 1$) and costly investment friction ($\gamma_K = 0$). The parameters used in the numerical example are summarized in the following Table 4 with total population normalized to $L = 1$.

The prices of manufactured goods in the closed economy setting and from the rest of the world are shown in Figure 4. When the price is above the rest of the world, it means that the small economy has a comparative advantage in agricultural production. Therefore, if the small economy starts trade liberalization when the price of manufactured goods is above the rest of the world, then the small economy exports agricultural goods and imports manufactured goods. Vice versa, the small economy exports manufactured goods and imports agricultural goods when the price is

Description	Parameter	Value
Initial sectoral TFP - agricultural	A_{a0}	4
Initial base productivity - manufacturing	$\overline{A}_{m0}$	1
Initial sectoral TFP - service	A_{s0}	0.4
Sectoral TFP growth - agricultural	g_a	0.029
Sectoral TFP growth - service	g_s	0.011
Capital intensity - agricultural	α_{Ka}	0.28
Capital intensity - manufacturing	α_{Km}	0.20
Capital intensity - service	α_{Ks}	0.28
Labor intensity - agricultural	α_{La}	0.60
Labor intensity - manufacturing	α_{Lm}	0.55
Labor intensity - service	α_{Ls}	0.60
Demand shifter - agricultural	ω_a	1
Demand shifter - manufacturing	ω_m	1
Demand shifter - service	ω_s	1
Income elasticity - agricultural	ε_a	0.05
Income elasticity - manufacturing	ε_m	1
Income elasticity - service	ε_s	2.2
Intertemporal elasticity	σ	2
Price elasticity	σ_c	0.5
Depreciation rate - physical capital	δ_K	0.05
Depreciation rate - organizational capital	δ_H	0.08
Learning - manufacturing TFP	γ_A	0.02
Learning - organizational capital	γ_H	0.05
Learning - international	γ_T	0.01
Costly investment	γ_K	0
Firm-specific productivity Pareto parameter	ρ	4.5
Advanced operation TFP gain	ν	0.05
Organizational capital reserved rent	$\underline{\phi}$	0.05
Labor market friction	$\overline{\theta}$	1
Time discount rate	β	0.96
Newborn firm	N	0.6
Population	L	1
Initial physical capital stock	K_0	0.05
Initial manufacturing firm	N_0	0.4
Initial organizational capital stock	H_0^s	0.2

Table 4: Parameters for benchmark model

below the rest of the world. Figure 4 suggests that the small economy in the benchmark case can export manufactured goods during the period of trade liberalization if it chooses to liberalize trade in period 29.

Figure 5 shows the ratio of the final goods output at different timing of liberalization to the closed economy case. That is, $\{\frac{y_t^{\hat{t}}}{y_t^c}\}$. For example, if the economy chooses to liberalize in period 1, the real output increases about 3% at most compared to the output in the closed economy case. However, the difference shrinks after period 7 and the economy eventually underperforms after period 20 compared to the closed economy case. The reason is that the manufacturing sector in the small economy lacks a comparative advantage and cannot compete with others in the international market. This can be seen in Figure 6 to Figure 8.

Figure 6 shows that the entry threshold η_{nt} increases after the liberalization of the trade, leading to a larger withdrawal of manufacturing firms (Figure 7). Based on equation (9), the base manufacturing productivity grows slower due to fewer operating firms and the less advanced operation is chosen (Figure 8). The scenario of low manufacturing production capacity and prolonged recovery in the instant liberalization case in Figure 7 and Figure 8 are the numerical example described in Corollary 1. Although faster physical accumulation can compensate for productivity reduction (Figure 9), the net effect is still negative, reducing aggregate output and subsequent growth.

In terms of impact on welfare, Figure 10 shows the discounted utility of the household in different periods of trade liberalization. We normalize the discounted utility of the household when the small economy chooses to liberalize trade in the first period as 0. The same figure suggests that the small economy should liberalize trade in period 30, which allows the small economy to export manufactured goods. Comparing the optimal liberalization timing case to the instant liberalization case, I find that welfare actually decreases in the first 3 periods for the instant liberalization case because people save more to smooth future consumption as shown in Figure 9. The welfare for the instant liberalization case becomes higher from period 4 to 16 due to larger physical capital stocks. However, the extra gain from period 4 to 16 is not enough to compensate for the welfare differences after period 16.

Finally, I investigate how the speed of structural transformation responds to different time of trade liberalization. Here I focus on the time when the employment share in the manufacturing sector passes the employment share in the agricultural sector, and I call that period *the structural break moment*. Figure 12 shows that the structural break moment occurs in period 50 for the closed economy case. Once the economy chooses to optimally liberalize trade, the structural break moment occurs in period 33, suggesting that trade speeds up the structural transformation process as in the Korean case in Uy et al. (2013). On the other hand, if the small economy chooses to liberalize in first period, the manufacturing sector shrinks immediately and takes longer to achieve the structural break moment (Figure 13).

In this section, I demonstrate how the timing of trade liberalization affects the path of output and the reallocation of production resources. If the objective function for policymakers in the small economy is the discounted utility function of the household and the small economy does not have the comparative advantage in manufacturing production in period 1, then there exist cases that delaying trade liberalization raises the welfare.

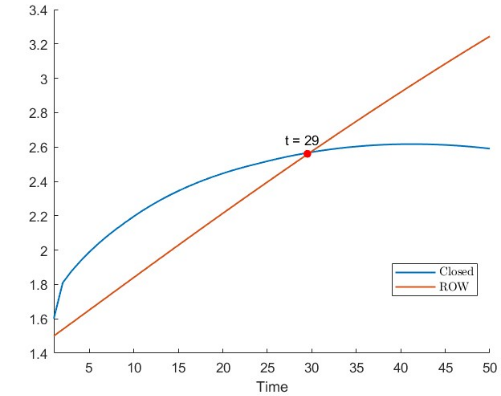

Figure 4: p_{mt}/p_{at} path

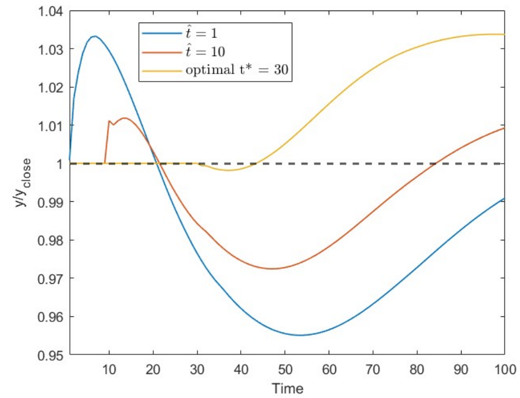

Figure 5: Relative real GDP path

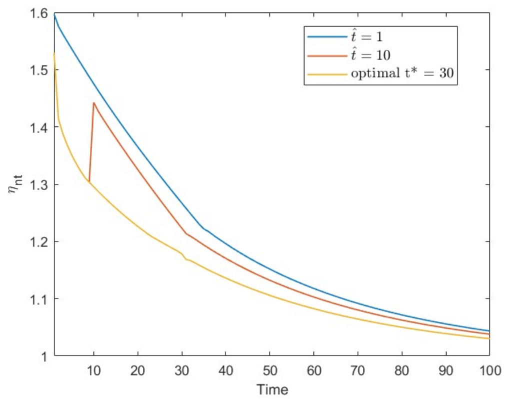

Figure 6: Entry Threshold

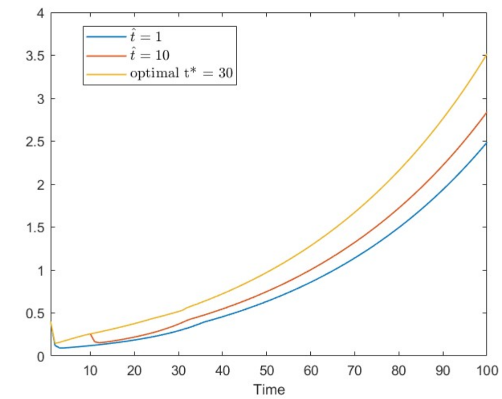

Figure 7: N_t path

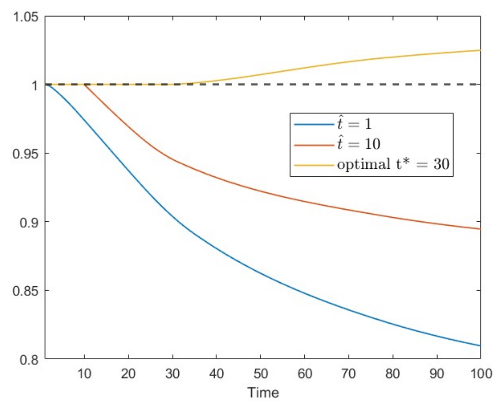

Figure 8: Base manufacturing productivity

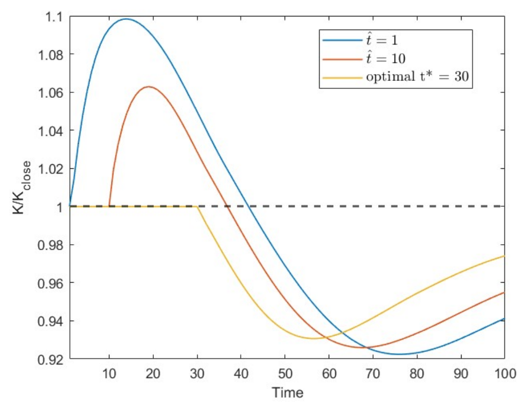

Figure 9: Relative K_t path

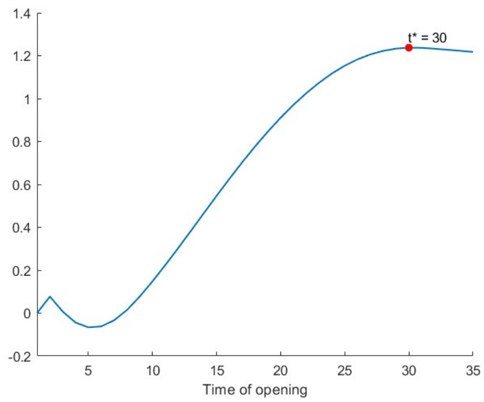

Figure 10: Discounted utility

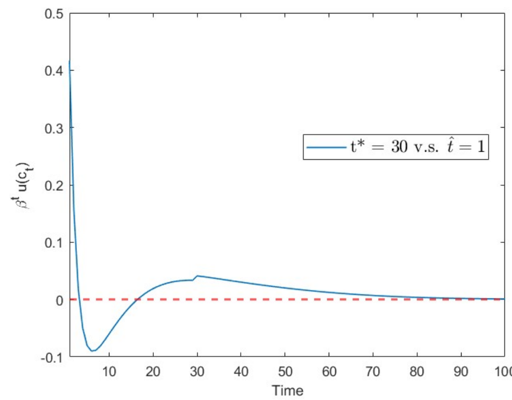

Figure 11: Utility difference

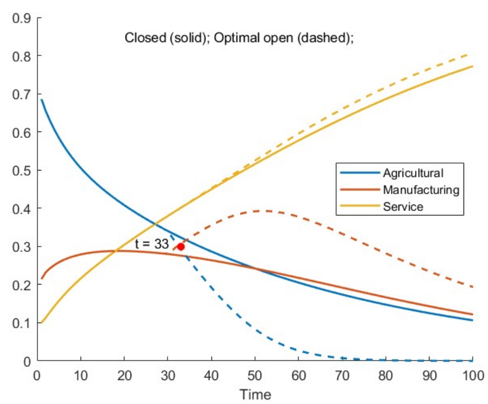

Figure 12: Employment share change – closed v.s. optimal opening

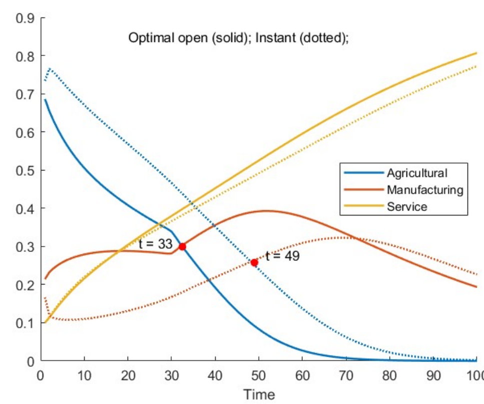

Figure 13: Employment share change – optimal v.s. instant opening

5 Calibration

In this section, I apply my model to access low-income countries' WTO accession decision. We calibrate to 77 low- and lower middle-income countries defined by the World Bank back in 1991. We first describe how I estimate a part of the parameters that are common across the sample and the country-specific parameters that can be calculated directly from the data. Then I provide the summary statistics for the calibrated country-specific parameters and the target moments. Finally, I demonstrate the distribution of difference to the optimal timing of trade liberalization and the consumption equivalence variance for each country.

5.1 Fixed parameters

Table 5 summarizes the source of data that I use in calibration. Estimation includes sector-specific factor intensity, income elasticity, and price elasticity. Moreover, I assign commonly used values for the time discount rate and the intertemporal elasticity.

Description	Source	Periods
Log real GDP per capita	World Bank	1991-2022
Sectoral value-added at constant price	World Bank	1991-2022
Sectoral value-added at current price	World Bank	1991-2022
Sectoral net export value	World Bank	1991-2022
Inflation dataset	World Bank	1991-2022
Sectoral employment	International Labour Organization	1991-2022
WTO membership	World Trade Organization	1991-2022
Physical capital	Penn World Table 10.0	1991-2020
Physical capital depreciation	Penn World Table 10.0	1991-2020
Human development index	United Nations	1991-2022

Table 5: Data source and sample period

Capital and labor intensity The sectoral value-added at constant price (Y^r_{int}) from sector i country n at time t can be written as

$$Y^r_{int} = \overline{p}_{in} A_{int} (\kappa_{int} K_{nt})^{\triangle\alpha_{Ki} + \alpha_{Kj}} L_{int}^{\triangle\alpha_{Li} + \alpha_{Lj}}$$

where $\overline{p}_{in}$ is the constant level of sectoral price, κ_{int} is the share of capital usage, and $\triangle\alpha_{Ki}$ and $\triangle\alpha_{Li}$ are differences between sector i, and the reference sector j in capital and labor intensity respectively. After taking log, I have the following expression

$$\log Y^r_{int} = \log(\overline{p}_{in} A_{int}) + (\triangle\alpha_{Ki} + \alpha_{Kj})[\log(\kappa_{int}) + \log(K_{nt})] + (\triangle\alpha_{Li} + \alpha_{Lj}) \log(L_{int}). \tag{30}$$

By running the following regression, I have the estimated sectoral capital and labor intensity parameters.

$$\begin{aligned}\log Y^r_{int} =&(\beta_{0a} + \sum_{j=m,s} \beta_{0j} D_{j,\,int})+ \\ &(\beta_{Ka} + \sum_{j=m,s} \beta_{Kj} D_{j,\,int}) \log(K_{nt}) + (\beta_{La} + \sum_{j=m,s} \beta_{Lj} D_{j,\,int}) \log(L_{int})+ \\ &(\beta_{3a} + \sum_{j=m,s} \beta_{3j} D_{j,\,int}) \triangle t + (\beta_{4a} + \sum_{j=m,s} \beta_{4j} D_{j,\,int}) \triangle t^2 + \beta_n country + \varepsilon_{int},\end{aligned} \tag{31}$$

which $D_{m,\,int}$ and $D_{s,\,int}$ are sector dummy variables for manufacturing and service sector implying agricultural sector is the reference sector. In this case, I can identify sectoral capital and labor intensity without knowing exactly capital usage in each sector.[12] We also include the deterministic time trend and the country fixed effect. Table 6 reports the main estimation result, which contains point estimators and t-test p-value.

	α_{Ka}	$\triangle\alpha_{Km}$	$\triangle\alpha_{Ks}$	α_{La}	$\triangle\alpha_{Lm}$	$\triangle\alpha_{Ls}$
Estimation	0.280	0.323	0.211	0.492	-0.244	-0.233
p-value	0.000	0.000	0.000	0.000	0.000	0.000
country	103	obs.	8108	Adj. R^2	0.967	
Result	a	m	s			
α_{Ki}	0.280	0.604	0.491			
α_{Li}	0.492	0.248	0.259			

Table 6: Factor intensity

Income and price elasticity First, I recover the price level for each sector using $p_{int} = \frac{Y_{int}}{Y^r_{int}}$, where Y_{int} is the sectoral value-added at current price from sector i in country n at time t. To estimate the income elasticity and the price elasticity, I then rely on the optimal condition of the household. Given the price, the optimal consumption is

$$\log(c_{int}) = \log(\omega_{ci}) - \sigma_c \log(\frac{p_{int}}{e_{int}}) + \varepsilon_i(1-\sigma_c)\log(y^r_{nt}),$$

[12] In fact, the physical capital allocation depends on capital intensity in production function and capital utilization. The capital intensity is assumed to be time-invariant and has been taken extra care with sector and country fixed effects. The capital utilization co-moves with the sectoral TFP level, which is captured through $\{\beta_{0j}, \beta_{3j}, \beta_{4j}\}$.

which is the log of equation (11). To connect it to aggregate data, I use aggregate sectoral consumption expenditure share equation (12), which is

$$\log(\mu_{int}) = \log(\frac{p_{int}C_{int}}{E_{int}}) = \log(\omega_{ci}) + (1-\sigma_c)\log(\frac{p_{int}}{E_{int}}) + \varepsilon_i(1-\sigma_c)\log(Y^r_{nt}). \tag{32}$$

We use service sector as reference sector and rewrite the equation (32) as

$$\log(\frac{\mu_{int}}{\mu_{snt}}) = \log(\frac{\omega_{ci}}{\omega_{cs}}) + (\varepsilon_i - \varepsilon_s)(1-\sigma_c)\log(Y^r_{nt}) + (1-\sigma_c)\log(\frac{p_{int}}{p_{snt}}). \tag{33}$$

To account for the impact of trade, I calculate domestic sectoral absorption, $p_{int}C_{int} = Y_{int} - NX_{int}$, which is sectoral value-added minus net sectoral export value, and use it as the sectoral consumption expenditure. Notice that I treat service goods as non-tradeable goods and, hence $p_{snt}C_{snt} = Y_{snt}$. By running the following regression, I have the estimated income elasticity and price elasticity parameters for each sector.

$$\log(\frac{\mu_{int}}{\mu_{snt}}) = (\beta_0 + \beta_{0a}D_{ant}) + (\beta_1 + \beta_{1a}D_{ant})\log(Y^r_{nt}) + \beta_2\log(\frac{p_{int}}{p_{snt}}) + \beta_n country + \varepsilon_{int}, \tag{34}$$

which D_{ant} is sector dummy variables for the agricultural sector. Based on my estimation, I set ω_{cs} and ε_s equal to 1 to get $\{\omega_{ca},\ \omega_{cm}\}$ and $\{\varepsilon_{ca},\ \varepsilon_{cm}\}$. Following Comin et al. (2021), I normalize $\epsilon_m = 1$ and $\sum \omega_{ci} = 1$.[13] Table 7 summarizes the main estimation result, which contains point estimators and the p-value of the t-test.

	σ_c	$\varepsilon_a - \varepsilon_s$	$\varepsilon_m - \varepsilon_s$	$\log(\omega_{ca}/\omega_{cs})$	$\log(\omega_{cm}/\omega_{cs})$
Estimation	0.703	-0.668	-0.454	3.323	2.964
p-value	0.000	0.000	0.000	0.059	0.000
country	108	obs.	6516	Adj. R^2	0.642
Result	a	m	s		
ε_i	0.608	1.000	1.831		
ω_i	0.577	0.403	0.021		

Table 7: Preference parameters

Time discounted rate and intertemporal elasticity We follow Comin et al. (2021) and set the time discount rate $\beta = 0.96$ and intertemporal elasticity $\sigma = 2.2$.

[13] For ε_i, I set $\varepsilon_s = 1$ and recover ε_a and ε_m. Then I divide ε_i by ε_m to get the parameters after normalization. For ω_{ci}, I use $\sum_i \omega_{ci} = (\sum_i \frac{\omega_{ci}}{\omega_{cs}})\omega_{cs} = 1$ to pin down ω_{cs} and the rest.

5.2 Computable country-specific parameters

Labor market friction From the optimal condition of the firm, the wage rate equals the marginal productivity of labor. That is, $\theta W_{nt} = \alpha_{La} Y_{ant}$, $W_{nt} = \alpha_{Lm} Y_{mnt} = \alpha_{Ls} Y_{snt}$, and Y_{int} is current price value-added from sector i country n at time t. We use the average wage rate differences between the agricultural sector and the other two sectors as the labor market friction parameter θ in each country. That is,

$$\theta = \left[\sum_{n}^{N_c} \sum_{t}^{T} \frac{\alpha_{Lm} Y_{mnt} / L_{mnt}}{\sum_{i=a,s} \alpha_{Li} Y_{it} / \sum_{i=a,s} L_{int}} \right] / (N_c T),$$

Sectoral TFP growth With factor intensity and labor market friction parameter, I can rewrite the real sectoral value-added as

$$Y^r_{int} = \overline{p}_{in} A_{int} \left[\frac{\alpha_{Ki}}{\alpha_{Li}} \frac{[1 + (\theta - 1) D_{a,\,int}] K_{nt} \ell_{int}}{\overline{\alpha}_{KLnt}} \right]^{\alpha_{Ki}} L_{int}^{\alpha_{Li}},$$

which $D_{a,\,int}$ is the dummy variable for the agricultural sector, $\overline{\alpha}_{KLnt} = \frac{\alpha_{Ka}\theta}{\alpha_{La}} \ell_{ant} + \frac{\alpha_{Km}}{\alpha_{Lm}} \ell_{mnt} + \frac{\alpha_{Ks}}{\alpha_{Ls}} \ell_{snt}$, and ℓ_{int} is the sectoral employment share. The sectoral growth rate is calculated by dividing two consecutive real sectoral value-added.

$$\log(1 + g_{int+1}) = \log(\frac{Y^r_{int+1}}{Y^r_{int}}) - \alpha_{Ki} \log(\frac{K_{nt+1} \ell_{int+1} / \overline{\alpha}_{KLnt+1}}{K_{nt} \ell_{int} / \overline{\alpha}_{KLnt}}) - \alpha_{Li} \log(\frac{L_{int+1}}{L_{int}}) \tag{35}$$

We take the median of positive growth rate across the sample periods to be $\{g_a,\ g_s\}$ in each country.[14]

Capital depreciation rates The capital depreciation rate δ_K is the depreciation rate from PWT 10.0. We calculate the weighted average depreciation rate of the capital stock for each country. That is,

$$\delta_{Kn} = \frac{\sum_t \delta_{K,\,nt} K_{nt}}{\sum_t K_{nt}}$$

[14] The productivity growth in the manufacturing sector can be calculated as well. Since it is endogenously determined in the model, I omit it in this step.

5.3 Calibrated country-specific parameters

In the following, I calibrate the rest of the parameters by matching the moments generated from the model to the target moments from the data. We use the relative supply of organizational capital, $h^s_t = H^s_t/(N_t(1-\delta_N)+N)$ to target the organizational capital index (OCI) for the target country. Furthermore, I normalize the population to $L = 1$ and the initial relative organizational capital supply $h^s_0 = 1$. Here is the list of remaining parameters to be calibrated.

Symbol	Description
ρ	Pareto distribution shape parameter
ν	Efficient gain of advanced operation
δ_H	Organizational capital depreciation rate
γ_H	Organizational capital accumulation rate
γ_A	Manufacturing TFP spillover rate - operation
γ_T	Manufacturing TFP spillover rate - international
N_0	Initial manufacturing firm size
N	Manufacturing newborn firm size
A_{a0}	Initial agricultural TFP
$\overline{A}_{m0}$	Initial manufacturing base productivity
A_{s0}	Initial service TFP
k_0	Physical capital stock per household
$\underline{\phi}$	Reserved rent for organizational capital
$\overline{p}^w_m$	World traded goods price ratio

Table 8: Calibrated country-specific parameters (# = 14)

Notice that for the world price ratio between traded goods, I set it as a country-specific constant parameter. The reason is that I find that the ratio stays steady around 1 (see Figure 14) if I use the World Bank inflation dataset to construct the time series of the international price ratio. That is, $\frac{p^w_{mt}}{p^w_{at}} = \overline{p}^w_m$ for all t, in my calibrated model.[15]

[15] Specifically, I first set 2015 as base year and recover the price level for producer median price index and food median price index, which is taken as price for manufactured goods and agricultural goods. We then construct the price ratio by dividing the producer price index by the food price index for the global economy. The ratio stays around 1 which allows me to assign one fixed constant number as the global tradable price ratio for each country.

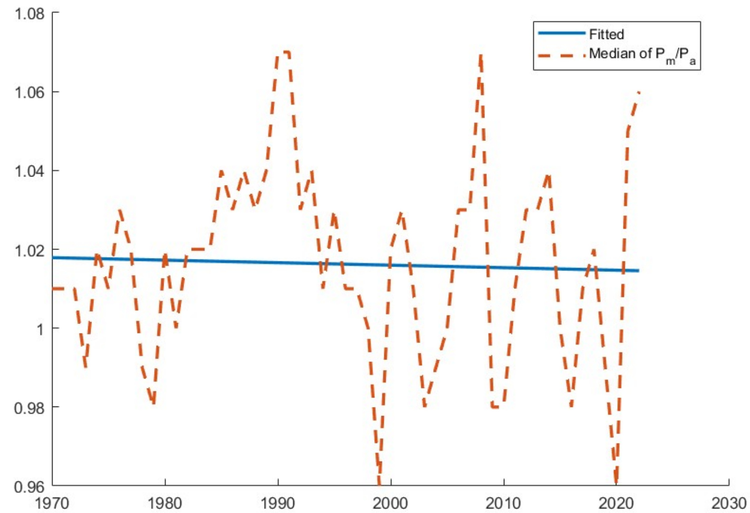

Figure 14: $\frac{p^w_{mt}}{p^w_{at}}$ Path (Global)

Target moments We target moments from the following time series: organizational capital index, employment share in the agricultural and manufacturing sector, share of household expenditure in the agricultural and service sector. We take both the mean and the growth rate for such time series as the target moments. Table 9 summarizes the value for fixed parameters and the mean of country-specific parameters used in the calibrated model. Table 10 provides an overall fitness between the target moments and the moments generated by the model in the sample countries. On average, the fit is good. The deviation for some moment is huge, partially because the target moment is relatively small. For example, Madagascar (ISO code MDG) has the largest deviation in the manufacturing employment share in my calibration. Nevertheless, the fitness between real time series and model-generated time series remains good (see Figure 15).

Description	Parameter	Value
Common parameters		
Capital intensity - agricultural	α_{Ka}	0.2801
Capital intensity - manufacturing	α_{Km}	0.6035
Capital intensity - service	α_{Ks}	0.4906
Labor intensity - agricultural	α_{La}	0.4921
Labor intensity - manufacturing	α_{Lm}	0.2478
Labor intensity - service	α_{Ls}	0.2589
Demand shifter - agricultural	ω_a	0.5767
Demand shifter - manufacturing	ω_m	0.4025
Demand shifter - service	ω_s	0.0208
Income elasticity - agricultural	ε_a	0.6084
Income elasticity - manufacturing	ε_m	1.0000
Income elasticity - service	ε_s	1.8308
Price elasticity	σ_c	0.7028
Time discount rate	β	0.9600
Intertemporal elasticity	σ	2.2000
Normalization		
Population	L	1.0000
Initial relative organizational capital stock	h_0^s	1.0000
Country-specific parameters (mean)		
Initial physical capital stock per household	k_0	388.60
Initial sectoral TFP - agricultural	$log(A_{a0})$	6.1969
Initial base productivity - manufacturing	$log(\overline{A}_{m0})$	4.9694
Initial sectoral TFP - service	$log(A_{s0})$	-1.0861
Sectoral TFP growth - agricultural	g_a	0.0431
Sectoral TFP growth - service	g_s	0.0254
Initial manufacturing firm	N_0	0.0118
Newborn firm	N	0.0292
Pareto distribution shape parameter	ρ	10.955
Efficient gain of advanced operation	ν	0.2725
Depreciation rate - organizational capital	δ_H	0.0580
Depreciation rate - physical capital	δ_K	0.0448
Learning - manufacturing TFP	γ_A	0.0270
Learning - organizational capital	γ_H	0.1675
Learning - international	γ_T	0.0164
Costly investment	γ_K	8.6905
Organizational capital reserved rent	$\underline{\phi}$	127.93
Tradable goods price ratio	$\overline{p}_m^w$	3.5992
Labor market friction	θ	0.6755

Table 9: Calibrated parameters

Table 10: target moments and fitting

	Moments		Deviation		
Description	Data mean	Model mean	Mean	Max	Min
Organizational Capital Index					
1991 – 2001 average	1.0733	1.0437	0.0446	0.1517	0.0003
2002 – 2012 average	1.2826	1.2948	0.0395	0.1804	0.0003
1991 – 2001 growth	1.0149	1.0133	0.0049	0.0287	0.0000
2002 – 2012 growth	1.0149	1.0204	0.0092	0.0265	0.0003
Agricultural Employment Share					
1991 – 2001 average	0.4751	0.4830	0.0402	0.2459	0.0008
2002 – 2012 average	0.4202	0.4108	0.0887	0.6417	0.0025
1991 – 2001 growth	0.9915	0.9892	0.0087	0.0646	0.0000
2002 – 2012 growth	0.9839	0.9716	0.0163	0.1439	0.0001
Manufacturing Employment Share					
1991 – 2001 average	0.1619	0.1629	0.0780	0.5477	0.0022
2002 – 2012 average	0.1674	0.1716	0.0780	1.1000	0.0023
1991 – 2001 growth	1.0022	0.9966	0.0165	0.1010	0.0006
2002 – 2012 growth	1.0109	1.0136	0.0182	0.0923	0.0000
Agricultural Expenditure Share					
1991 – 2012 average	0.2027	0.2162	0.1125	0.6488	0.0010
1991 – 2012 growth	0.9814	0.9742	0.0229	0.1045	0.0000
Service Expenditure Share					
1991 – 2012 average	0.5168	0.5392	0.1176	0.5086	0.0003
1991 – 2012 growth	1.0102	1.0096	0.0095	0.0382	0.0001

Notes: (1) Organizational capital index is normalized as 1 in 1991 across countries. (2) The deviation is defined as $\frac{|\text{generated moment-target moment}|}{\text{target moment}}$.

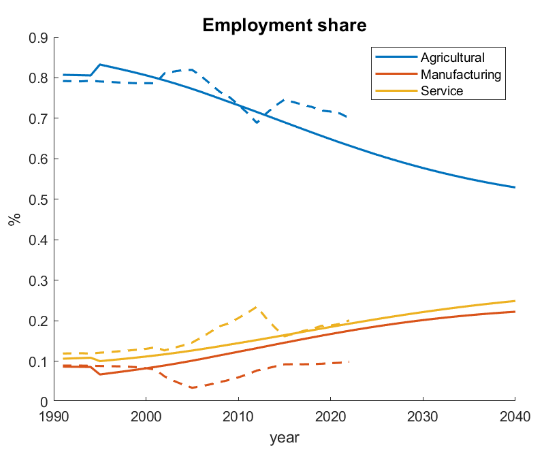

Figure 15: Madagascar case

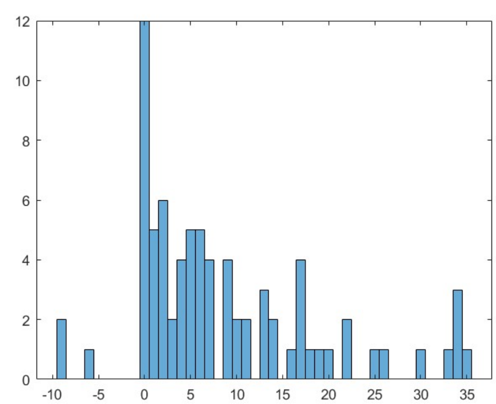

Figure 16: Distance to optimal timing

5.4 Optimal timing of WTO accession

After setting the parameters to match the target moments for each country, I conduct a thought experiment to see when the optimal timing is for each country to join the WTO given these parameters. We allow the government to join the WTO any time between 1995 and 2030 to maximize the sum of discounted household utility for 200 periods. The result is shown in Figure 16 which means the years a particular country should wait to join the WTO compared to its real WTO accession year.

The calibration result suggests that 12 of the 77 (15.6%) countries liberalize trade at the right time, while 62 of the 77 (80.5%), which are classified as the "*early group*", should liberalize trade later with a median waiting time of 8 years. Meanwhile, there are 3 countries (Cambodia, Laos, Vietnam) that are classified as the "*late group*" because they should liberalize trade earlier with a median delaying time of 9 years.[16] We then measure the welfare gain for each country through consumption equivalence variation. Specifically, I denote the consumption path under the original liberalization timing as $\{c_t\}$ and the consumption path under the optimal liberalization timing as $\{c_t^*\}$, and find the $\lambda > 0$ such that

$$\sum_{t=0}^{\infty} \beta^t \frac{(c_t(1+\lambda))^{1-\sigma}}{1-\sigma} = \sum_{t=0}^{\infty} \beta^t \frac{(c_t^*)^{1-\sigma}}{1-\sigma}.$$

We find that the median increase in consumption is 0.2290% for the late group and is 0.0856% for the early group. Table 11 provides the first to third quantiles of the time difference between optimal timing and welfare increase measured by consumption equivalent variation for both groups.

		Time difference			Consumption equivalence (λ)		
Group	Number	Q1	Q2	Q3	Q1	Q2	Q3
Early	62	+4	+8	+17	0.0217%	0.0856%	0.4612%
Late	3	-9	-9	-6.75	0.0834%	0.2290%	0.4031%

Table 11: Calibrated result

[16] For the detailed listing of country for each group, please refer to Appendix.

5.5 Counterfactual

In this section, I consider three types of counterfactuals to see how optimal trade liberalization timing and welfare are affected across 77 countries under each counterfactual. Additionally, I allow 3 countries in the late group to use industrial policy to replicate the manufacturing value-added path while they stay closed and liberalize trade as they did in the real world. For each country, I use the calibrated parameters from the previous calibration exercise. I first consider the following three counterfactuals and consider the industrial policy.

Counterfactual 1 - constant growth rate in $\overline{A}_{mt}$. The first counterfactual I consider is that the growth rate in the manufacturing base productivity $\overline{A}_{mt}$ is constant, which equals g_m, and keep the rest of the model the same. Specifically, g_m for each country is the average growth rate of the manufacturing base productivity when the country liberalizes optimally in the benchmark calibration. The result shows that more countries liberalizes optimally comparing to the benchmark calibration. Additionally, more countries liberalizes too late in the counterfactual. The reason is that, the growth in the manufacturing base productivity in the benchmark model relies on organizational capital stock. A slower growth in the organizational capital leads to a slower growth in the manufacturing base productivity. Such situation is alleviated as organizational capital keeps accumulated. But in this counterfactual, the growth in the manufacturing base productivity does not rely on organizational capital. Furthermore, the average growth rate is higher than the one in the benchmark optimal case in the beginning periods. This allows countries to liberalize earlier. The left panel of figure 17 compares the distribution of difference to optimal timing between benchmark case and counterfactual 1. Table 12 provides the first to third quantiles of the time difference between optimal timing and welfare increase measured by consumption equivalent variation for both groups.

		Time difference			Consumption equivalence		
Group	Number	Q1	Q2	Q3	Q1	Q2	Q3
Early	50	+4	+8	+20	0.0240%	0.1986%	0.4226%
Late	6	-8	-5	-3	0.0560%	0.2256%	0.5312%

Table 12: Counterfactual 1 - result

Counterfactual 2 - constant entry rate $1-G(\eta_{nt})$ and constant accumulation rate in H_t. The second counterfactual I consider is that the entry rate for manufacturing firms $1-G(\eta_{nt})$ is fixed and the accumulation rate in the organizational capital stock H_t is constant, and keep the rest of the model the same. Specifically, $1-G(\eta_{nt})$ for each country equals the average entry rate when the country liberalizes optimally in the benchmark calibration. For the accumulation of organizational capital $\triangle H_t$, it equals $\gamma_H \frac{\rho}{\rho-1} N_{t+1}$, which does not depend on firm's operation decision. The result shows that even more countries liberalizes optimally comparing to the benchmark calibration. But at the same time, more countries should postpone their liberalization more than 30 years. The reason that more countries liberalize optimally is the same as the counterfactual 1, with one difference that the base productivity is affected by the evolution of organizational capital and the number of firms. When the accumulation of organizational capital is fast enough comparing to the growth in the number of firms, the growth in base productivity is fast as well. However, if the accumulation of organizational capital is slow comparing to the growth in the number of firms, then more organizational capital would be allocated into basic operation, which leads to a slower growth in the base productivity. This causes some countries need to postpone liberalization even longer. The middle panel of figure 17 compares the distribution of difference to optimal timing between benchmark case and counterfactual 2. Table 13 provides the first to third quantiles of the time difference between optimal timing and welfare increase measured by consumption equivalent variation for both groups.

		Time difference			Consumption equivalence		
Group	Number	Q1	Q2	Q3	Q1	Q2	Q3
Early	47	+6	+14	+20.8	0.0408%	0.2903%	1.0346%
Late	6	-8	-5	-4	0.0533%	0.2959%	0.5569%

Table 13: Counterfactual 2 - result

Counterfactual 3 - constant growth rate in H_t. The final counterfactual I consider is that the growth rate in the organizational capital stock H_t is constant, which equals g_H, and keep the rest of the model the same. The growth rate g_H for each country equals the average growth rate in organizational capital when the country liberalizes optimally in the benchmark calibration. The result shows that more countries should postpone their liberalization more than 30 years. The reason that more countries should postpone their liberalization is opposite from the one in the counterfactual 1. In the benchmark calibration, the base productivity grows slower in the beginning because of the insufficient organizational capital, and the average growth rate of the base productivity is higher in the beginning periods mitigates the problem. However, in the benchmark calibration, the organizational capital grows faster in the beginning because of the lower base of organizational capital, and the average growth rate of the organizational capital is lower in the beginning periods limits the growth in the base productivity in this counterfactual exercise. This causes more countries need to postpone liberalization even longer. The right panel of figure 17 compares the distribution of difference to optimal timing between benchmark case and counterfactual 3. Table 14 provides the first to third quantiles of the time difference between optimal timing and welfare increase measured by consumption equivalent variation for both groups.

		Time difference			Consumption equivalence		
Group	Number	Q1	Q2	Q3	Q1	Q2	Q3
Early	69	+12.5	+26	+35	0.0755%	0.5341%	1.3986%
Late	2	-9	-5	-1	0.0100%	0.0676%	0.1252%

Table 14: Counterfactual 3 - result

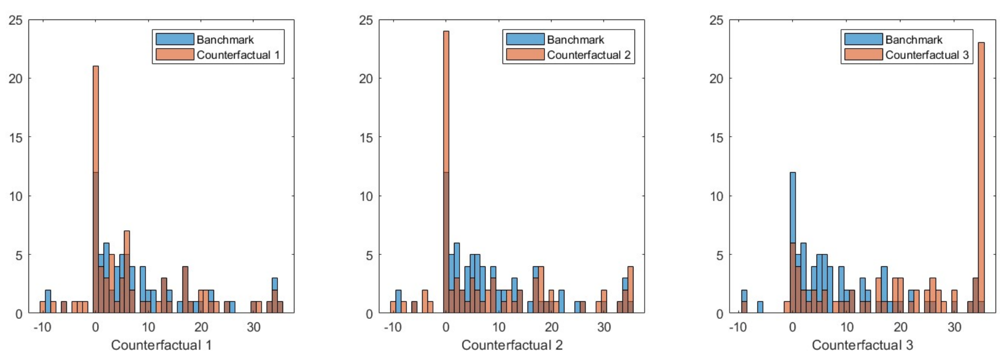

Figure 17: Counterfactual

Industrial policy Here I consider that 3 countries in the late group (Cambodia, Lao, Vietnam) use industrial policy, which is financed by a lump-sum tax, to replicate the manufacturing value-added path in the optimal liberalization equilibrium and liberalizes as they did in the real world. For example, in the right of Figure 18, the first vertical dashed line indicates the optimal liberalization time while the second vertical dashed line indicates the real liberalization time for Vietnam. This exercise considers that country uses industrial policy to replicate the red path between two vertical lines and liberalizes after the second vertical line. The government announces and commits to the plan of industrial policy and the timing of liberalization at the first vertical line.

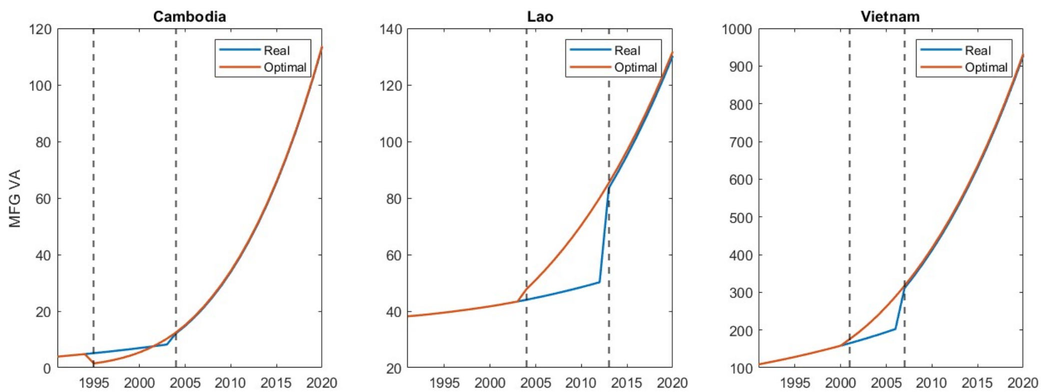

Figure 18: Manufacturing value-added path

The comparison of consumption equivalent variation between optimal liberalization and industrial policy and the average subsidy rate are summarized below. The results are quite different across countries. First, by taking benchmark calibration as the reference, three countries achieve a higher welfare in the optimal liberalization case. However, only Cambodia achieves higher welfare in when industrial policy is allowed. Second, the subsidy is financed through a lump-sum tax on households. The average subsidy rate implies that both Lao and Vietnam need to subsidize heavily to replicate the manufacturing value-added path while Cambodia needs to impose a tax and rebates to households through a lump-sum transfer. Last, when industrial policy stops, the manufacturing value-added is lower than the optimal liberalization case for Lao and Vietnam as shown in Figure 19. Such different patterns across countries suggest that the industrial policy does not always work in this model.

Country	Cambodia	Lao	Vietnam
Optimal liberalization	0.0003 %	0.0046 %	0.0023%
Industrial policy	0.0869 %	-0.0452 %	-0.0442 %
Average subsidy rate	-41.69 %	57.18 %	44.74 %

Table 15: Consumption equivalent variation comparison

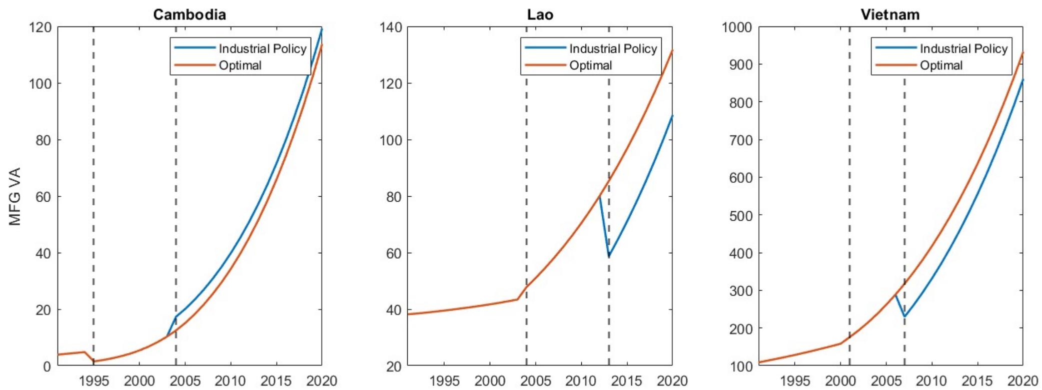

Figure 19: Manufacturing value-added path after policy

6 Conclusion

In this paper, I argue that the timing of trade liberalization has a significant implication on the path of economic growth for a low-income country. Through the lens of the model, I find that the optimal timing of trade liberalization depends on what comparative advantage a country has and whether the manufacturing sector is strong enough to survive from international competition. Specifically, if manufacturing production capacity shrinks after trade liberalization, the shrinkage leads to slower accumulation of organizational capital and a slower growth in productivity of the manufacturing sector. This paper highlights that such slower growth in the manufacturing production capacity is the cost of early trade liberalization which is often ignored. Hence, "the sooner, the better" argument does not apply to all low-income countries. This paper bridges structural transformation literature and international trade literature to evaluate low-income countries' decision on WTO accession. I find that 62 out of 77 (80.5%) countries in my sample belong to the early group and should postpone their decision on WTO accession with a median waiting time of 8 years. If countries in the early group act optimally, the median increase in welfare, which is measured by consumption equivalent variation, is 0.0856%.

In the counterfactual exercise, I find that i) countries can liberalize earlier if manufacturing base productivity grows exogenously; ii) countries need to postpone liberalization if organizational capital grows exogenously; iii) the effect on the liberalization timing is mixed if entry threshold is fixed. I also consider the situation that 3 countries in the late group can use industrial policy financed by a lump-sum tax from households when they stay closed. By replicating the manufacturing value-added path in the optimal liberalization case, I find only Cambodia achieves a higher welfare while both Lao and Vietnam end up with a lower welfare, suggesting that, in this model, industrial policy does not always yield positive results.

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Appendix A. Proofs and derivations

Derivation of (11) and (13) The household maximization problem is following.

$$\max_{\{c_{it},\, c_t,\, k_{t+1}\}} \sum_{t=0} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}$$

$$s.t.\ \overline{W}_t + R_t k_t + \phi_t h_t^d + \pi_t = e_t = \mathcal{P}_t\, y_t = \mathcal{P}_t(c_t + x_t)$$

$$\overline{W}_t = \theta \ell_{at} W_t + \ell_{mt} W_t + \ell_{st} W_t,\ \theta \in (0,1)$$

$$\left\{ e_t = \min_{\{c_{it}\}} \sum_{i\in\{a,m,s\}} p_{it} c_{it}, \quad s.t. \sum_{i\in\{a,m,s\}} \omega_{ci} \left(\frac{c_{it}}{y_t^{\varepsilon_i}}\right)^{\frac{\sigma_c-1}{\sigma_c}} = 1 \right\}$$

$$k_{t+1} = (1-\delta_K)k_t + \frac{x_t}{1+\gamma_K}, \quad \gamma_K \geq 0, \quad k_0,\ h_t \text{ are given.}$$

We first solve the cost minimization problem which is

$$\min_{\{c_{it}\}} \sum_{i\in\{a,m,s\}} p_{it} c_{it} \quad s.t. \sum_{i\in\{a,m,s\}} \omega_{ci}^{\frac{1}{\sigma_c}} \left(\frac{c_{it}}{y_t^{\varepsilon_i}}\right)^{\frac{\sigma_c-1}{\sigma_c}} = 1,\ y_t \text{ is given.}$$

The Lagrangian is

$$\min_{\{c_{it}\}} \sum_{i\in\{a,m,s\}} p_{it} c_{it} - \lambda \left[\sum_{i\in\{a,m,s\}} \omega_{ci}^{\frac{1}{\sigma_c}} \left(\frac{c_{it}}{y_t^{\varepsilon_i}}\right)^{\frac{\sigma_c-1}{\sigma_c}} - 1 \right],$$

which λ is the Lagrange multiplier, and the first order derivative with respect to c_i is

$$p_{it} c_{it} = \lambda \frac{\sigma_c - 1}{\sigma_c} \omega_{ci}^{\frac{1}{\sigma_c}} \left(\frac{c_{it}}{y_t^{\varepsilon_i}}\right)^{\frac{\sigma_c-1}{\sigma_c}}.$$

By definition, the nominal expenditure is

$$e_t = \sum_{i\in\{a,m,s\}} p_{it} c_{it} = \lambda \frac{\sigma_c - 1}{\sigma_c} \sum_{i\in\{a,m,s\}} \omega_{ci}^{\frac{1}{\sigma_c}} \left(\frac{c_{it}}{y_t^{\varepsilon_i}}\right)^{\frac{\sigma_c-1}{\sigma_c}} = \lambda \frac{\sigma_c - 1}{\sigma_c}.$$

Substituting back to the first-order derivative with respect to c_{it}, I get

$$c_{it} = \left(\frac{p_{it}}{e_t}\right)^{-\sigma_c} \omega_{ci} y_t^{\varepsilon_i(1-\sigma_c)},$$

which is equation (11). Using equation (11), I derive

$$\begin{aligned}
\mu_{it} &= \frac{p_{it}c_{it}}{e_t} = \left(\frac{p_{it}}{e_t}\right)^{1-\sigma_c} \omega_{ci} y_t^{\varepsilon_i(1-\sigma_c)}; \\
e_t &= \sum_{i\in\{a,m,s\}} p_{it}c_{it} = \left[\sum_{i\in\{a,m,s\}} p_{it}^{1-\sigma_c} \omega_{ci}^{\frac{1}{\sigma_c}} y_t^{\varepsilon_i(1-\sigma_c)}\right]^{\frac{1}{1-\sigma_c}}; \\
\mathcal{P}_t &= \frac{e_t}{y_t} = \left[\sum_{i\in\{a,m,s\}} p_{it}^{1-\sigma_c} \omega_{ci}^{\frac{1}{\sigma_c}} y_t^{(\varepsilon_i-1)(1-\sigma_c)}\right]^{\frac{1}{1-\sigma_c}}.
\end{aligned}$$

The solution of the cost minimization problem suggests the minimum nominal expenditure to produce a certain level of final goods. In other words, I know that the maximum level of final goods can be reached at a given level of nominal expenditure. Then it is the consumption-saving problem, which is below.

$$\max_{\{c_t\}} \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}$$

$$s.t.\ \mathcal{P}_t y_t = e_t = \overline{W}_t + R_t k_t + \phi_t h_t + \pi_t, \quad k_{t+1} = (1-\delta_K)k_t + \frac{x_t}{1+\gamma_K}, \quad c_t + x_t = y_t$$

The Lagrangian is

$$\max_{\{c_t\}} \sum_{t=0}^{\infty} \beta^t \left\{ \frac{c_t^{1-\sigma}}{1-\sigma} + \lambda_t^c \left[\overline{W}_t + R_t k_t + \phi_t h_t + \pi_t - \underbrace{\mathcal{P}_t \left(c_t + (1+\gamma_K)(k_{t+1} - (1-\delta_K)k_t)\right)}_{=e_t} \right] \right\},$$

which λ_t^c is the period t Lagrange multiplier, and the first order derivative with respect to c_t and k_{t+1} are

$$\begin{aligned}
c_t^{-\sigma} &= \lambda_t \frac{\partial e_t}{\partial y_t}\frac{\partial y_t}{\partial c_t} = \lambda_t^c \mathcal{P}_t \bar{\varepsilon}_t; \\
\beta^t \lambda_t^c \frac{\partial e_t}{\partial y_t}\frac{\partial y_t}{\partial x_t}\frac{\partial x_t}{\partial k_{t+1}} &= \beta^{t+1}\lambda_{t+1}^c \left[R_{t+1} - \frac{\partial e_{t+1}}{\partial y_{t+1}}\frac{\partial y_{t+1}}{\partial x_{t+1}}\frac{\partial x_{t+1}}{\partial k_{t+1}}\right] \\
\Rightarrow \quad \lambda_t^c \mathcal{P}_t \bar{\varepsilon}_t (1+\gamma_K) &= \beta \lambda_{t+1}^c \left[R_{t+1} + \mathcal{P}_{t+1}\bar{\varepsilon}_{t+1}(1+\gamma_K)(1-\delta_K)\right].
\end{aligned}$$

The detailed derivations are as follows.

$$\begin{aligned}
\frac{\partial e_t}{\partial y_t} &= \left[\sum_{i\in\{a,m,s\}} p_i^{1-\sigma_c} \omega_{ci}^{\frac{1}{\sigma_c}} y_t^{\varepsilon_i(1-\sigma_c)}\right]^{\frac{1}{1-\sigma_c}-1} \left[\sum_{i\in\{a,m,s\}} p_i^{1-\sigma_c} \omega_{ci}^{\frac{1}{\sigma_c}} y_t^{\varepsilon_i(1-\sigma_c)} \varepsilon_i\right] y_t^{-1} \\
&= \frac{e_t^{\sigma_c} e_t^{1-\sigma_c}}{y_t} \sum_{i\in\{a,m,s\}} \varepsilon_i \mu_{it} = \mathcal{P}_t \bar{\varepsilon}_t;
\end{aligned}$$

$$\frac{\partial y_t}{\partial c_t} = \frac{\partial y_t}{\partial x_t} = 1; \quad \frac{\partial x_t}{\partial k_{t+1}} = (1+\gamma_K); \quad \frac{\partial x_{t+1}}{\partial k_{t+1}} = -(1+\gamma_K)(1+\delta_K).$$

The Euler equation (13) is therefore

$$\left(\frac{c_{t+1}}{c_t}\right)^{\sigma} = \frac{\lambda_t \mathcal{P}_t \bar{\varepsilon}_t}{\lambda_{t+1}\mathcal{P}_{t+1}\bar{\varepsilon}_{t+1}} = \beta \left[\frac{R_{t+1}}{\mathcal{P}_t \bar{\varepsilon}_{t+1}(1+\gamma_K)} + 1 - \delta_K\right].$$

Proof of Lemma 1 For given F_t and ϕ_t, the relation is $\eta_{bt} \geq \eta_{a1t} \geq \eta_{a2t}$ if $\nu \geq 1$ and it is $\eta_{a2t} > \eta_{a1t} > \eta_{bt}$ if $\nu \in (0,1)$.

Hence, if $\nu \geq 1$, then $\underline{\eta}_{at} = \eta_{a1t}$ and $\underline{\eta}_{nt} = \eta_{a1t}$ according to the definition. Hence, all firms' owners choose to operate at the advanced level if they choose to stay and operate. If $\nu \in (0,1)$, then $\underline{\eta}_{at} = \eta_{a2t}$ and $\underline{\eta}_{nt} = \eta_{bt}$ according to the definition. The condition implies that some firms can make a profit no matter whether the basic or advanced level of operation is chosen. Therefore, firms' owners choose to operate at the advanced level only if it is more profitable to do so compared to the basic operation. The following figures provide an illustration of two cases. □

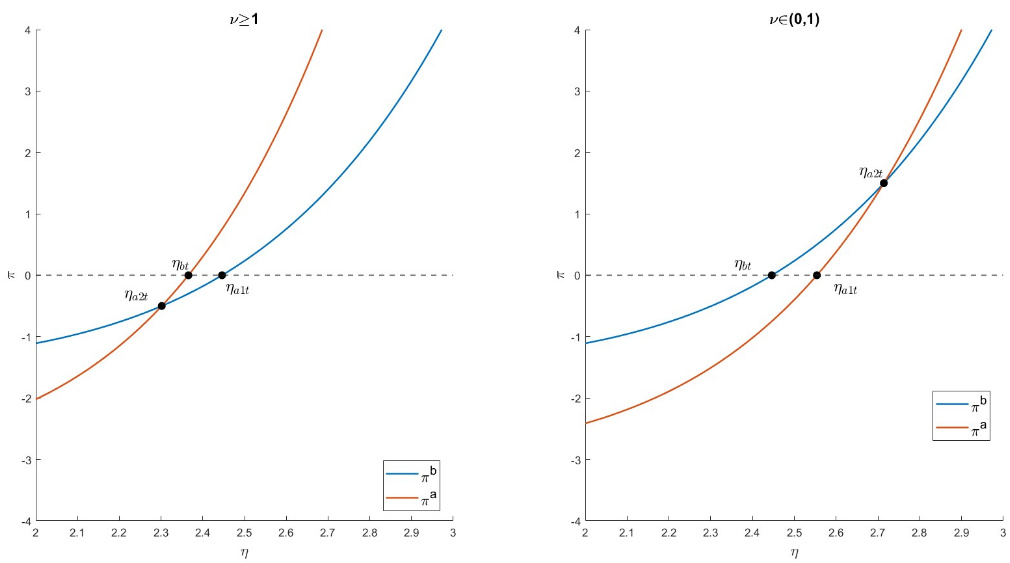

Figure 20: Lemma 1

Proof of Lemma 2 Given $\nu < 1$, the relative demand of organizational capital is

$$h_t^d = \underbrace{1 - G(\eta_{nt})}_{\equiv h_t^{db}} + \underbrace{1 - G(\eta_{at})}_{\equiv h_t^{da}} = \eta_{nt}^{-\rho} + \eta_{at}^{-\rho} = (\max\{1,\ F_t \phi_t^{\alpha_{Hm}}\})^{-\rho} + (\max\{1,\ F_t (\frac{\phi_t}{\nu})^{\alpha_{Hm}}\})^{-\rho}.$$

Notice that h_t^d is decreasing in $F_t \in ((\frac{\phi_t}{\nu})^{-\alpha_{Hm}},\ \infty)$ for all $\phi_t \geq \underline{\phi}$. When the rental price $\phi_t = \underline{\phi}$, all the relative demand for organizational capital (h_t^d) will be satisfied if $h_t^d \leq h_t^s$. Once demand is higher than h_t^s, no additional organizational capital will be provided and the price will need to increase to clean the market. As a result, there must exist a threshold $\underline{F}_t$ such that $h_t^d = (\max\{1,\ \underline{F}_t \underline{\phi}^{\alpha_{Hm}}\})^{-\rho} + (\max\{1,\ \underline{F}_t (\underline{\phi}/\nu)^{\alpha_{Hm}}\})^{-\rho} = h_t^s$. Obviously, if $F_t \leq \underline{F}_t$, then $h_t^d = (\max\{1,\ F_t \underline{\phi}^{\alpha_{Hm}}\})^{-\rho} + (\max\{1,\ F_t (\underline{\phi}/\nu)^{\alpha_{Hm}}\})^{-\rho} \geq h_t^s$ and the rent has to rise $\phi_t \geq \underline{\phi}$. Vice versa. If $F_t > \underline{F}_t$, then $h_t^d = (\max\{1,\ F_t \underline{\phi}^{\alpha_{Hm}}\})^{-\rho} + (\max\{1,\ F_t (\underline{\phi}/\nu)^{\alpha_{Hm}}\})^{-\rho} < h_t^s$ and the rent stay at $\phi_t \geq \underline{\phi}$ and some organizational capital are unused. $\square$

The following figures are graphic illustrations. The figure on the left illustrates how the demand for organizational capital for advanced operation (blue line, h^{da}), basic operation (red line, h^{db}), and the relative demand for organizational capital (yellow line, h^d) respond to the change in the rental price ϕ. The figure on the right demonstrates the constrained case of Lemma 2, which is from the red line to the yellow line. In such a case, the demand for organizational capital increases as F_t decreases, but the supply of organizational capital is fixed and therefore the price will increase, i.e. the red line moves closer to the yellow line. It also includes the weak demand case (blue line). In the blue line case, the demand for organizational capital increases as F_t decreases, i.e. the blue line moves closer to the red line. However, if the demand is not strong enough, then the rental price stays at $\underline{\phi}$.

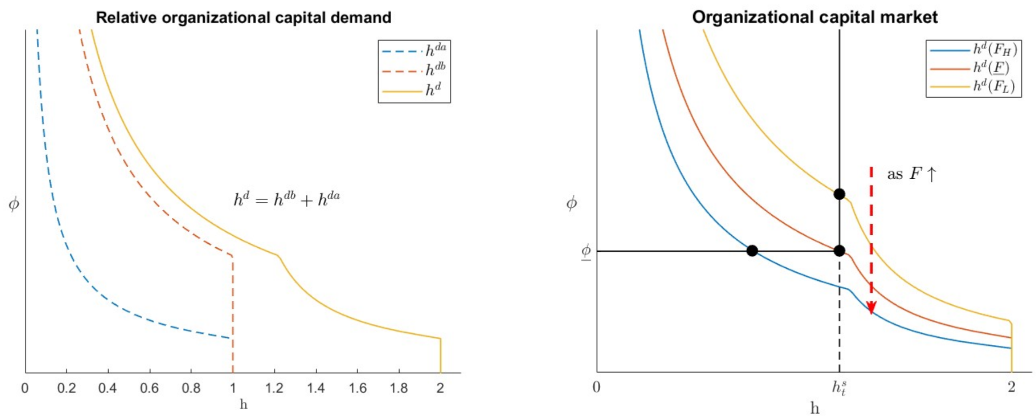

Figure 21: Lemma 2

Proof of Lemma 3 Assume Assumption 2 holds. Here I drop the time subscript for simplicity. The optimal production for each manufacturing firm is

$$y_{mj} = \left(A_{mj}^{\xi}\right)^{\frac{1}{\alpha_{Hm}}} \left(\frac{\alpha_{Km}}{R/p_m}\right)^{\frac{\alpha_{Km}}{\alpha_{Hm}}} \left(\frac{\alpha_{Lm}}{W/p_m}\right)^{\frac{\alpha_{Lm}}{\alpha_{Hm}}}.$$

Therefore, the aggregate production for manufacturing sector is

$$\begin{aligned}
Y_m &= \left[\int_{\eta_n}^{\eta_a} y_{mj} g(\eta) d\eta + \int_{\eta_a}^{\infty} y_{mj} g(\eta) d\eta\right] N_p \\
&= \left[\overline{A}_m^{\frac{1}{\alpha_{Hm}}} \rho \left(\int_{\eta_n}^{\infty} \eta^{\frac{1}{\alpha_{Hm}}-\rho-1} d\eta + \nu \int_{\eta_a}^{\infty} \eta^{\frac{1}{\alpha_{Hm}}-\rho-1} d\eta\right) N_p\right] \left(\frac{\alpha_{Km}}{R/p_m}\right)^{\frac{\alpha_{Km}}{\alpha_{Hm}}} \left(\frac{\alpha_{Lm}}{W/p_m}\right)^{\frac{\alpha_{Lm}}{\alpha_{Hm}}} \\
&= \overline{A}_m^{\frac{1}{\alpha_{Hm}}} \left(\frac{\alpha_{Hm}\rho}{\alpha_{Hm}\rho - 1}\right) \left[\eta_n^{\frac{1}{\alpha_{Hm}}-\rho} + \nu(\eta_a^{\frac{1}{\alpha_{Hm}}-\rho})\right] N_p \left(\frac{\alpha_{Km}}{R/p_m}\right)^{\frac{\alpha_{Km}}{\alpha_{Hm}}} \left(\frac{\alpha_{Lm}}{W/p_m}\right)^{\frac{\alpha_{Lm}}{\alpha_{Hm}}} \\
&= A_m^{\frac{1}{\alpha_{Hm}}} \left(\frac{\alpha_{Km}}{R/p_m}\right)^{\frac{\alpha_{Km}}{\alpha_{Hm}}} \left(\frac{\alpha_{Lm}}{W/p_m}\right)^{\frac{\alpha_{Lm}}{\alpha_{Hm}}} \\
&= A_m \left[A_m \left(\frac{\alpha_{Km}}{R/p_m}\right)^{1-\alpha_{Lm}} \left(\frac{\alpha_{Lm}}{W/p_m}\right)^{\alpha_{Lm}}\right]^{\frac{\alpha_{Km}}{\alpha_{Hm}}} \left[A_m \left(\frac{\alpha_{Km}}{R/p_m}\right)^{\alpha_{Km}} \left(\frac{\alpha_{Lm}}{W/p_m}\right)^{1-\alpha_{Km}}\right]^{\frac{\alpha_{Lm}}{\alpha_{Hm}}} \\
&= A_m K_m^{\alpha_{Km}} L_m^{\alpha_{Lm}},
\end{aligned}$$

and $A_m = \overline{A}_m \left\{\left(\frac{\alpha_{Hm}\rho}{\alpha_{Hm}\rho - 1}\right) \left[\eta_n^{\frac{1}{\alpha_{Hm}}-\rho} + \nu(\eta_a^{\frac{1}{\alpha_{Hm}}-\rho})\right] N_p\right\}^{\alpha_{Hm}}$. To make it well-defined, I need to impose Assumption 2. Specifically, the integrals in the second line are finite only if Assumption 2 holds. $\square$

Proof of Proposition 1 Based on equation (22) in Lemma 3, the manufacturing production capacity for manufacturing sector is

$$A_m = \overline{A}_m \left\{ \left(\frac{\alpha_{Hm}\rho}{\alpha_{Hm}\rho - 1} \right) \left[\eta_n^{\frac{1}{\alpha_{Hm}} - \rho} + \nu(\eta_a^{\frac{1}{\alpha_{Hm}} - \rho}) \right] N_p \right\}^{\alpha_{Hm}}.$$

Given Assumption 2 holds, it is obvious to see that

$$\begin{aligned}
\frac{\partial A_m}{\partial \eta_n} &= \underbrace{(1 - \alpha_{Hm}\rho)}_{<0} A_m(\eta_n^{\frac{1}{\alpha_{Hm}} - \rho - 1}) \left[\eta_n^{\frac{1}{\alpha_{Hm}} - \rho} + \nu(\eta_a^{\frac{1}{\alpha_{Hm}} - \rho}) \right]^{-1} < 0 \\
\frac{\partial A_m}{\partial \eta_a} &= \underbrace{(1 - \alpha_{Hm}\rho)}_{<0} \nu A_m(\eta_n^{\frac{1}{\alpha_{Hm}} - \rho - 1}) \left[\eta_n^{\frac{1}{\alpha_{Hm}} - \rho} + \nu(\eta_a^{\frac{1}{\alpha_{Hm}} - \rho}) \right]^{-1} < 0 \\
\frac{\partial A_m}{\partial \overline{A}_m} &= \left\{ \left(\frac{\alpha_{Hm}\rho}{\alpha_{Hm}\rho - 1} \right) \left[\eta_n^{\frac{1}{\alpha_{Hm}} - \rho} + \nu(\eta_a^{\frac{1}{\alpha_{Hm}} - \rho}) \right] N_p \right\}^{\alpha_{Hm}} > 0 \\
\frac{\partial A_m}{\partial N_p} &= \frac{\alpha_{Hm} A_m}{N_p} > 0.
\end{aligned}$$

If $F_t < \underline{F}_t$, Lemma 2 implies $h_t^d = \eta_{nt}^{-\rho} + \eta_{at}^{-\rho} = h_t^s$. Hence, a reduction in h_t^s must increase the entry or advanced threshold. Given the same condition, $\eta_{at} = 1$ implies $\eta_{nt} = 1$, while the reverse is not true. Therefore, η_{at} must first increase to accommodate the reduction in h_t^s. If $\eta_{nt} > 1$ before the reduction in h_t^s, then $\eta_{nt} > 1$ also increases in response to the reduction in h_t^s. $\square$

Proof of Corollary 1 This can be inferred from Proposition 1. Suppose that there is a shock and the number of potential manufacturing firms drops. Recovery depends on the increase in $\overline{A}_m$ and N_p or the decrease in η_n and η_a. The smaller size of the newborn firm N leads to a smaller number of potential manufacturing firms. A higher reserved rent for organizational capital $\underline{\phi}$ and a slower growth of organizational capital increase the thresholds η_n and η_a, which reduces the growth in $\overline{A}_m$. $\square$

Proof of Proposition 2 Equation (26) implies that trade must be balanced. That is,

$$(Y_{at}^{\dagger} - Lc_{at}^{\dagger}) + \frac{p_{mt}^w}{p_{at}^w}(Y_{mt}^{\dagger} - Lc_{mt}^{\dagger}) = 0,$$

where the variables with dagger means the equilibrium outcomes when trade is liberalized. Notice that when the economy is closed, the same equation holds with equilibrium prices $\frac{p_{mt}^c}{p_{at}^c}$ and additional market clearing conditions. That is,

$$\underbrace{(Y_{at} - Lc_{at})}_{=0} + \frac{p^c_{mt}}{p^c_{at}} \underbrace{(Y_{mt} - Lc_{mt})}_{=0} = 0.$$

Now if $\frac{p^w_{mt}}{p^w_{at}} > \frac{p_{mt}}{p_{at}}$, the production of manufactured goods is more profitable and hence the manufactured production increases, which decreases agricultural production, that is, $Y^\dagger_{mt} > Y_{mt}$ and $Y^\dagger_{at} < Y_{at}$. Since income increases, the demand for both goods also increases. That is, $c^\dagger_{mt} > c_{mt}$ and $c^\dagger_{at} > c_{at}$. Hence, I know $Y^\dagger_{at} - Lc^\dagger_{at} < 0$ (net import of agricultural goods) which implies $Y^\dagger_{mt} - Lc^\dagger_{mt} > 0$ (net export of manufactured goods). The case for $\frac{p^w_{mt}}{p^w_{at}} < \frac{p^c_{mt}}{p^c_{at}}$ is similar. □

Proof of Proposition 3 For any given $h^s_t > 0$ and N_t, I define

$$Q(\eta_{nt}) = \gamma_H \frac{\rho}{\rho - 1} \eta_{nt} (h^s_t)^{-1} + \left(\frac{N_t}{N_t + N} - \delta_H \right) \eta^\rho_{nt} - 1, \quad \eta_{nt} \in [1, \infty).$$

The first derivative with respect to η_{nt} is

$$Q'(\eta_{nt}) = q(\eta_{nt}) = \gamma_H \frac{\rho}{\rho - 1} (h^s_t)^{-1} + \rho \left(\frac{N_t}{N_t + N} - \delta_H \right) \eta^{\rho-1}_{nt}.$$

We know that $\frac{h^s_{t+1}}{h^s_t} \geq 1$ if and only if $Q(\eta_{nt}) \geq 0$. Hence, I examine each case as follows. Notice that $\rho > \frac{1}{\alpha_{Hm}}$ from Assumption 2 implies $\rho > 1$.

Case 1 $Q(1) \geq 0$ and $\frac{N_t}{N_t+N} \geq \delta_H$: The latter condition ensures $q(\eta_{nt}) > 0$ for all $\eta_{nt} \in [1, \infty)$, and $Q(1) \geq 0$ further implies $Q(\eta_{nt}) \geq 0$ for all $\eta_{nt} \in [1, \infty)$. Thus, $\frac{h^s_{t+1}}{h^s_t} \geq 1$ for all $\eta_{nt} \in [1, \infty)$.

Case 2 $Q(1) < 0$ and $\frac{N_t}{N_t+N} \geq \delta_H$: Following the same argument in Case 1, there exists a $\eta^\dagger_2$ such that $Q(\eta_{nt}) \geq 0$ for all $\eta_{nt} \in [\eta^\dagger_2, \infty)$ because $Q(\eta_{nt})$ increases in η_{nt}. Thus, $\frac{h^s_{t+1}}{h^s_t} \geq 1$ if and only if $\eta_{nt} \in [\eta^\dagger_2, \infty)$.

Case 3 $Q(1) \geq 0$ and $\frac{N_t}{N_t+N} < \delta_H$: The argument is the same as in Case 1 but with one difference. Now, the latter condition ensures that $q(\eta_{nt})$ eventually becomes negative and stays negative as η_{nt} increases, which implies that there exists $\eta^\dagger_3$ such that $Q(\eta_{nt}) < 0$ when $\eta_{nt} > \eta^\dagger_3$. But with $Q(1) \geq 0$, I can still have $Q(\eta_{nt}) \geq 0$ for all $\eta_{nt} \in [1, \eta^\dagger_3]$. Thus, $\frac{h^s_{t+1}}{h^s_t} \geq 1$ if and only if $\eta_{nt} \in [1, \eta^\dagger_3]$.

Case 4 $Q(1) < 0$ and $\frac{N_t}{N_t+N} < \delta_H$: We know $q(0) = \gamma_H \frac{\rho}{\rho-1}(h_t^s)^{-1} > 0$ and $\partial q(\eta)/\partial\eta < 0$ for all $\eta > 0$. Therefore, $Q(\eta)$ is a hump-shaped function over $(0, \infty)$. Hence, I can derive

$$\widehat{\eta} = \arg \max_{\eta_{nt}\in[0,\,\infty)} Q(\eta_{nt}) = \left[\frac{\gamma_H}{(\rho-1)h_t^s}\left(\delta_H - \frac{N_t}{N_t+N}\right)^{-1}\right]^{\frac{1}{\rho-1}}.$$

- If $\widehat{\eta} \leq 1$, then the $Q(\eta_{nt}) \leq Q(1) < 0$ for all $\eta_{nt} \in [1,\ \infty)$. This implies $\frac{h_{t+1}^s}{h_t^s} < 1$ for all $\eta_{nt} \in [1,\ \infty)$, which is Case 4-1.
- If $\widehat{\eta} > 1$, then $Q(\eta_{nt}) \leq Q(\widehat{\eta})$ for all $\eta_{nt} \in [1,\ \infty)$.
  - If $Q(\widehat{\eta}) > 0$, then there exists $1 < \eta_4^\dagger < \eta_5^\dagger$ such that $Q(\eta_{nt}) < 0$ for all $\eta_{nt} \in [1,\ \eta_4^\dagger)$ and $\eta_{nt} > \eta_5^\dagger$ and $Q(\eta_{nt}) \geq 0$ for all $\eta_{nt} \in [\eta_4^\dagger,\ \eta_5^\dagger]$. This implies $\frac{h_{t+1}^s}{h_t^s} \geq 1$ if and only if $\eta_{nt} \in [\eta_4^\dagger,\ \eta_5^\dagger]$. This is Case 4-2.
  - If $Q(\widehat{\eta}) = 0$, then $\frac{h_{t+1}^s}{h_t^s} = 1$ if and only if $\eta_{nt} = \widehat{\eta}$, otherwise $\frac{h_{t+1}^s}{h_t^s} < 1$. This is Case 4-3.
  - If $Q(\widehat{\eta}) < 0$, then $Q(\eta_{nt}) < 0$ implies $\frac{h_{t+1}^s}{h_t^s} < 1$ for all $\eta_{nt} \in [1, \infty)$. This is Case 4-4.

□

Proof of Proposition 4 If $N_t \to \overline{N}$, then it implies that $\eta_{nt} = \overline{\eta}_n = (\frac{\overline{N}}{\overline{N}+N})^{\frac{-1}{\rho}}$ from equation (6). By iterating H_{t+1} backward to when the steady state starts, I know

$$H_{t+1} = \gamma_H \frac{\rho}{\rho-1}\overline{\eta}_n^{1-\rho}(\overline{N}+N)\sum_{i=s}^{t+1}(1-\delta_H)^i = \gamma_H \frac{\rho}{\rho-1}\overline{\eta}_n^{1-\rho}(\overline{N}+N)\frac{1-(1-\delta_H)^{t+1-s}}{\delta_H}.$$

Therefore, $\lim_{t\to\infty} H_{t+1} = \overline{H} = \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}\overline{\eta}_n^{1-\rho}(\overline{N}+N)$. This further implies

$$h_{t+1}^s = \overline{h}^s = \frac{\overline{H}}{\overline{N}+N} = \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}\overline{\eta}_n^{1-\rho}$$

in steady state. Notice that $\overline{h}^s \in (0,\ 2)$ because Assumption 4 implies $\frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1} \in (1,2)$ and $\overline{\eta}_n^{1-\rho} \in (0,1)$.

In the steady state, the relative prices, such as $\frac{W_t}{p_{mt}}$ and $\frac{R_t}{p_{mt}}$ are fixed. However, F_t is decreasing across periods because the manufacturing base productivity $\overline{A}_{mt}$ is increasing. The rise in the manufacturing base productivity implies that ϕ_t has to increase to make $(F_t\phi_t^{\alpha_{Hm}})^{-\rho}$ fixed. Once

$(F_t\phi_t^{\alpha_{Hm}})^{-\rho}$ is fixed, the threshold $\eta_{nt} = \overline{\eta}_n$ and $\eta_{at} = \overline{\eta}_a$, which means $h_t^d = 1-G(\eta_{nt})+1-G(\eta_{at}) = \overline{h}^d$. In addition, since ϕ_t keeps increasing, I know that $\phi_t > \underline{\phi}$ and thus $\overline{h}^d = \overline{h}^s$ in a steady state.

There are two possible outcomes: $\overline{\eta}_n = 1$ or $\overline{\eta}_n > 1$. The first outcome ($\overline{\eta}_n = 1$) is impossible because the law of motion for N_t suggests $\eta_{nt} = \overline{\eta}_n = (\frac{\overline{N}}{\overline{N}+N})^{\frac{-1}{\rho}} > 1$ from equation (6).

For the second outcome, if $\overline{\eta}_n > 1$, then I have $\overline{\eta}_a = \overline{\eta}_n \nu^{-\alpha_{Hm}}$ and

$$\overline{h}^d = \overline{\eta}_n[1+\nu^{\rho\alpha_{Hm}}] = \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}\overline{\eta}_n^{1-\rho}.$$

With some rearrangements, I have the expression

$$\overline{\eta}_n = \left[\frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}\right]^{-1}(1+\nu^{\rho\alpha_{Hm}}) = \max\{F_t\phi_t^{\alpha_{Hm}}, 1\} = F_t\phi_t^{\alpha_{Hm}}.$$

Assumption 4 ensures $\overline{\eta}_n > 1$ and hence $F_t\phi_t^{\alpha_{Hm}} = \left[\frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1} - 1\right]^{-1}(1+\nu^{\rho\alpha_{Hm}})$. The rest variables are as following

$$\begin{aligned}
\eta_{at} &\rightarrow \overline{\eta}_a = \overline{\eta}_n\nu^{-\alpha_{Hm}} \\
H_t &\rightarrow \overline{H} = \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}(\overline{N}+N)\overline{\eta}_n^{1-\rho} \\
N_t &\rightarrow \overline{N} = \frac{\overline{\eta}_n^{-\rho}}{1-\overline{\eta}_n^{-\rho}}N \\
h_t^s &\rightarrow = \overline{h}^s = \frac{\gamma_H}{\delta_H}\frac{\rho}{\rho-1}\overline{\eta}_n^{1-\rho} \in (0,\ 2).
\end{aligned}$$

□

Proof of Proposition 5 If the price sequence of the rest of the world $\{p_{mt}^w\}$ and the price sequence of the small closed economy $\{p_{mt}^c\}$ for $t \geq 0$, leads to the same path of $\{\eta_{nt}\}$ and $\{\eta_{at}\}$, then liberalization does not affect manufacturing production capacity, which implies that the evolution of production possibility frontier is the same after trade liberalization. The unchanged production possibility frontier implies that the closed economy equilibrium is feasible even in the open economy scenario. Additionally, trade liberalization merges the agricultural goods and manufactured goods market clearing conditions into one single trade balance condition, expanding the household's feasible set. The expanded feasible set increases household's utility. Therefore, it improves welfare by liberalizing trade for all $t \geq 1$. To maximize the discounted utility of household, the government should liberalize trade immediately. □

Appendix B. Detailed list of countries in both groups

In this appendix I provide the differences to optimal opening timing (Diff T) and consumption equivalent variations (CEV) for each country in the benchmark calibration (B) and three counterfactuals (C1 - C3). The detailed list is as follows.

ISO	Country Name	Diff T				CEV (%)			
		B	C1	C2	C3	B	C1	C2	C3
ALB	Albania	0	-2	-4	30	0.0000	0.0001	0.0005	0.0012
BGD	Bangladesh	0	0	0	23	0.0000	0.0000	0.0000	0.0039
BLZ	Belize	10	0	0	2	0.0008	0.0000	0.0000	0.0056
BEN	Benin	14	10	14	-1	0.0003	0.0002	0.0004	0.0001
BOL	Bolivia	5	0	0	35	0.0002	0.0000	0.0000	0.0055
BGR	Bulgaria	22	20	20	34	0.0013	0.0014	0.0016	0.0004
BFA	Burkina Faso	9	6	9	35	0.0058	0.0048	0.0048	0.0337
BDI	Burundi	18	17	17	35	0.0191	0.0179	0.0165	0.0318
KHM	Cambodia	-9	-3	-3	-9	0.0003	0.0006	0.0005	0.0013
CMR	Cameroon	7	5	6	35	0.0046	0.0042	0.0036	0.0137
CAF	Central African Republic	17	17	19	20	0.5400	0.5463	0.6008	0.6170
TCD	Chad	14	13	14	34	0.0049	0.0031	0.0064	0.0200
CHL	Chile	0	0	0	0	0.0000	0.0000	0.0000	0.0000
CHN	China	1	-6	-6	19	0.0009	0.0011	0.0017	0.0150
COL	Colombia	2	0	0	6	0.0000	0.0000	0.0000	0.0002
COD	Congo, Dem. Rep.	4	6	33	33	0.0015	0.0021	0.0097	0.0102
COG	Congo, Rep.	17	17	17	19	0.5415	0.5381	0.5159	0.5772
CRI	Costa Rica	0	2	0	0	0.0000	0.0000	0.0000	0.0000
CIV	Côte d'Ivoire	2	21	18	16	0.0002	0.0042	0.0039	0.0037
DOM	Dominican Republic	1	0	0	27	0.0001	0.0000	0.0000	0.0000
ECU	Ecuador	34	34	12	9	0.0008	0.0015	0.0010	0.0008
EGY	Egypt, Arab Rep.	0	0	0	35	0.0000	0.0000	0.0000	0.0015
SLV	El Salvador	2	2	2	35	0.0001	0.0001	0.0001	0.0035
SWZ	Eswatini	25	21	29	25	0.0001	0.0003	0.0002	0.0001
FJI	Fiji	6	6	8	0	0.0002	0.0002	0.0004	0.0000
GMB	Gambia, The	34	23	17	16	0.0009	0.0037	0.0037	0.0035
GHA	Ghana	7	-4	-4	35	0.0000	5.0000	5.0000	0.0004
GTM	Guatemala	35	35	35	20	0.0012	0.0009	0.0008	0.0029
GIN	Guinea	6	5	5	35	0.0032	0.0031	0.0030	0.0150

Table 16: Calibration result

ISO	Country Name	Diff T				CEV (%)			
		B	C1	C2	C3	B	C1	C2	C3
HTI	Haiti	5	34	34	34	0.0003	0.0040	0.0079	0.0069
HND	Honduras	4	1	0	35	0.0002	0.0000	0.0000	0.0043
IND	India	2	2	1	35	0.0005	0.0004	0.0004	0.0069
IDN	Indonesia	3	3	35	35	0.0003	0.0003	0.0028	0.0089
JAM	Jamaica	13	7	8	35	0.0013	0.0007	0.0003	0.0053
JOR	Jordan	30	30	30	20	0.0010	0.0009	0.0010	0.0007
KAZ	Kazakhstan	0	0	0	1	0.0000	0.0000	0.0000	0.0004
KEN	Kenya	5	7	0	11	0.0000	0.0000	0.0000	0.0004
KGZ	Kyrgyz Republic	9	9	11	11	0.2339	0.2277	0.2235	0.2356
LAO	Lao PDR	-9	-10	-10	10	0.0046	0.0053	0.0056	0.0020
LSO	Lesotho	6	6	6	6	0.0085	0.0029	0.0067	0.0086
MDG	Madagascar	20	20	20	23	0.6445	0.6441	0.6419	0.7491
MWI	Malawi	4	31	35	28	0.0008	0.0154	0.0181	0.0129
MYS	Malaysia	13	12	9	0	0.0004	0.0005	0.0005	0.0000
MDV	Maldives	0	0	0	1	0.0000	0.0000	0.0000	0.0016
MLI	Mali	33	33	34	14	0.0029	0.0027	0.0029	0.0031
MRT	Mauritania	16	14	18	2	0.0002	0.0001	0.0003	0.0001
MUS	Mauritius	0	1	2	1	0.0000	0.0000	0.0000	0.0000
MDA	Moldova	17	17	18	17	0.4017	0.4443	0.4878	0.4608
MNG	Mongolia	9	6	7	1	0.0005	0.0003	0.0004	0.0000
MAR	Morocco	11	0	12	35	0.0068	0.0000	0.0052	0.0197
MOZ	Mozambique	1	0	35	35	0.0003	0.0000	0.0138	0.0103
MMR	Myanmar	5	1	0	30	0.0004	0.0000	0.0000	0.0027
NAM	Namibia	2	0	0	3	0.0002	0.0000	0.0000	0.0003
NPL	Nepal	6	5	5	26	0.0010	0.0008	0.0008	0.0076
NIC	Nicaragua	10	0	0	13	0.0001	0.0000	0.0000	0.0003
NER	Niger	34	25	30	25	0.0082	0.0244	0.0106	0.0126
NGA	Nigeria	0	0	1	35	0.0000	0.0000	0.0002	0.0076
PAK	Pakistan	9	6	2	8	0.0003	0.0002	0.0000	0.0006
PAN	Panama	22	22	21	22	0.6876	0.6816	0.6715	0.6906
PRY	Paraguay	11	3	0	4	0.0002	0.0000	0.0000	0.0001
PER	Peru	7	3	0	35	0.0042	0.0029	0.0000	0.0126
PHL	Philippines	0	0	0	26	0.0000	0.0000	0.0000	0.0025
POL	Poland	1	0	0	35	0.0001	0.0000	0.0000	0.0050
ROU	Romania	19	18	18	19	1.3442	1.3026	1.2671	1.4031
SEN	Senegal	7	1	9	26	0.0015	0.0001	0.0014	0.0091
SLE	Sierra Leone	0	0	0	0	0.0000	0.0000	0.0000	0.0000
LKA	Sri Lanka	0	0	0	35	0.0000	0.0000	0.0000	0.0026

Calibration result (continued)

ISO	Country Name	Diff T				CEV (%)			
		B	C1	C2	C3	B	C1	C2	C3
LCA	St. Lucia	17	0	0	35	0.0004	0.0000	0.0000	0.0055
VCT	St. Vincent and the Grenadines	2	0	0	0	0.0000	0.0000	0.0000	0.0000
TZA	Tanzania	6	6	5	16	0.0034	0.0032	0.0029	0.0057
THA	Thailand	5	4	4	35	0.0023	0.0019	0.0018	0.0153
TGO	Togo	4	3	3	27	0.0002	0.0002	0.0001	0.0003
TUR	Türkiye	1	0	0	35	0.0001	0.0000	0.0000	0.0050
UGA	Uganda	13	13	13	35	0.0026	0.0020	0.0021	0.0201
UKR	Ukraine	3	3	3	4	0.0124	0.0109	0.0117	0.0214
VNM	Vietnam	-6	-8	-8	5	0.0023	0.0034	0.0042	0.0003
ZWE	Zimbabwe	26	13	26	35	0.0130	0.0024	0.0091	0.0254

Calibration result (continued)