Financial Development, Technology Adoption, and Structural Transformation in Developing Countries

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Abstract

Rodrik (2016) highlighted that developing countries are experiencing premature deindustrialization. This study develops a theoretical model to analyze the dynamics of industrialization and deindustrialization in developing economies and their integration with earlier industrialized countries. The model shows that integration with developed economies facilitates technology transfer and knowledge spillovers, which in turn stimulate catch-up growth—particularly in sectors that are further from the technological frontier. Since manufacturing is more technologically dynamic than services in developed economies, the productivity gap between developed and developing countries is larger in manufacturing than in services. As a result, developing economies experience faster productivity growth in manufacturing than in services, leading to a leapfrogging effect whereby they bypass intermediate stages of industrial development and transition earlier into the services sector. Moreover, the findings suggest that financial development acts as a catalyst for structural transformation by accelerating industrialization and facilitating the shift toward a service-based economy.

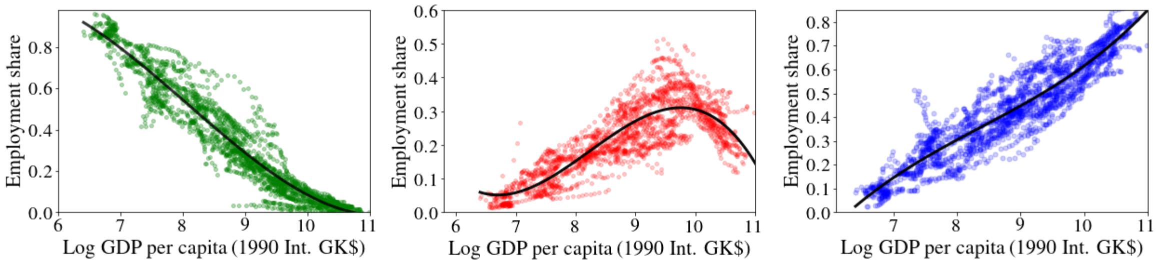
KEYWORDS: Structural Transformation, Premature Deindustrialization, Productivity Gap, Sectoral Productivity Growth, Financial Development, Technology Adoption.

JEL classification: E23, O11, O14, O31, O33, O40, O41, G28

1 Introduction

The concept of structural change, defined as the reallocation of resources across broad economic sectors like agriculture, manufacturing, and services, is a key facet of economic development. This was notably included in Kuznets (1967) as one of the main stylized facts of development. Despite this common pattern, it has been documented by economists that the industrialization paths of developing economies differ substantially from those observed in developed countries. This discrepancy could potentially be influenced by the backdrop of globalization context in which these economies operate. This paper examines how the interplay of integration with earlier industrialized economies and the level of financial development influences the trajectory of industrialization in developing countries.

During the first stages of development, structural change takes place when labor moves from agriculture to other sectors, and at advanced stages of development, manufacturing shrinks when services continue to grow. Figure I shows this pattern by plotting sectoral employment shares as a function of income for several countries during the period 1950 through 2010[1]. However, the "peak" of the hump of



(a) Agriculture **(b)** Manufacturing **(c)** Services

FIGURE I: Worldwide employment shares of agriculture, manufacturing, and services

manufacturing employment share has been lower at lower income levels for countries that industrialize in later years, what Rodrik (2016) called premature deindustrialization. Furthermore, in the literature, two main explanations have emerged to account for structural change: Engel's law and relative price effects. The first, and oldest mechanism, stipulates that households preferences shift from agriculture-related products to manufacturing industry and services as they get richer. The second mechanism, attributed to Baumol (1967), posits that asymmetric sectoral productivity growth induces structural change and accounts for different paths of deindustrialization across countries[2].

Virtually, almost all of the literature on structural change takes productivity changes as given, and effectively considers the implications of the exogenously given paths for productivity on the process of structural transformation. But if the paths of sectoral productivities differ significantly across countries, then it is important to ask what factors are responsible for these differences? Herrendorf et al. (2014) suggested to dig deeper into the factors that can explain these differences as they are more pronounced in particular sectors in particular countries. Meanwhile, recent research on endogenous economic growth

[1]Using Timmer et al. (2015) and Bolt & Van Zanden (2014) database, manufacturing employment is constructed as the sum of total employment in mining, manufacturing, utilities, and construction. Services is the sum of whole sale and retail trade; hotels and restaurants; transport, storage, and communications; finance, real state, and business services; and community, social, and personal services. Income per capita is measured in 1990 international Geary-Khamis dollars. The solid black line plots the OLS fitted values from a regression of the employment share on a cubic polynomial of income per capita.

[2]See, for example, Huneeus & Rogerson (2023) and Sposi et al. (2021)

emphasizes the significance of sectoral productivity in determining overall productivity through the adoption of technology.

Technological advancements primarily occur within specific industries, leading to varying rates of sector productivity growth (evidenced by studies such as Comin & Hobijn (2010), and Comin & Mestieri (2018)). Comin & Nanda (2019) and Avoumatsodo (2023) have shown that financial development differentially affects the intensity of use of adopted technologies. In this work, we first argue that financial development may have a distributional impact on productivity growth rates across various sectors. Sectors that are further from the technological frontier may experience more pronounced productivity increases as they catch up through financial development.

The objective of this paper, therefore, is to explore how financial development through the lens of technology adoption, contribute to the phenomenon of premature deindustrialization in developing countries. To do this, we develop a three-sector endogenous growth model that considers the adoption of technology as the main driver of sectoral productivity growth. Countries can access frontier[3] technological ideas through globalization. In this framework, each final good has one intermediate good which is produced by an entrepreneur who invests in technology adoption.

We introduce the assumption of financial constraints in the economy, stemming from limited financial development in developing countries. This implies that the total amount invested in technology adoption projects falls short of the optimal level due to the presence of significant financial constraints, which has been well-documented in developing countries. In the model, there is a direct cost associated with the quantity of adopted technology — the intensity of use of technology— and a sector-specific adjustment cost that reflects the expenses related to the implementation or use of the technology. These elements of the model help in capturing the nuances of technology adoption across different sectors and their impact on structural transformation.

The model demonstrates that as a sector moves further away from the technological frontier, its productivity growth rate tends to increase. This implies that sectors such as agriculture, which are typically farther from the frontier in developing countries, have the potential for higher rates of productivity growth. This suggests that there are opportunities for catching up and closing the productivity gap by adopting and implementing frontier technologies in sectors that are further behind.

The model also highlights an important finding regarding financial development and the processes of industrialization and deindustrialization. It shows that an increase in financial development has a dual effect on these processes. Specifically, during the phase of industrialization, higher levels of financial development accelerate the level of industrialization, leading to a more rapid transformation of the economy towards industrial sectors. This suggests that a well-developed financial system can facilitate the allocation of resources towards industrial activities, fostering economic growth and structural transformation. On the other hand, during the phase of deindustrialization, the model reveals that higher levels of financial development can actually contribute to the growth of services.

Moreover, the model examines how the process of industrialization in developing countries can be influenced when they engage with economies undergoing deindustrialization. Under certain assumptions regarding parameter values and sectoral productivity gaps at the onset of globalization, the model reveals that the level of industrialization in a country may be lower when it opens up to technologies

[3]The technological frontier, in this context, refers to the group of earlier industrialized countries that have achieved advanced levels of technological development and innovation. These countries often serve as benchmarks for technological progress and are characterized by their ability to push the frontier of knowledge and technology.

from countries already in the deindustrialization phase. The underlying reason is that after integration, the relative productivity gap with the frontier tends to be smaller in the services sector than in manufacturing[4]. Consequently, the variation in productivity growth rates in manufacturing will be higher than that in services, leading to an early shift towards services.

Related Literature. This paper is part of a recent and growing literature that seeks to understand the economic forces driving structural transformation[5], specifically the factors that explain different industrialization trajectories among countries. Our work aligns closely with the research of Sposi et al. (2021) and Huneeus & Rogerson (2023), as well as the seminal work of Fujiwara & Matsuyama (2022).

Sposi et al. (2021) employed a Ricardian trade model to explore the impact of trade integration and sector-biased productivity growth on deindustrialization. Their findings concur with those from Huneeus & Rogerson (2023) indicating that sector-biased productivity growth explains the patterns of deindustrialization observed across various countries. However, their model falls short in explaining why, upon integration with other countries, the manufacturing sector might see a more substantial relative productivity growth compared to the services sector.

Our model addresses this gap by explicating their concept of "importing" sector-biased productivity growth. It does this through the mechanisms of technology adoption, demonstrating that integrating with industrialized countries facilitates faster growth in the manufacturing sectors of developing countries compared to services. This is primarily because these industrialized countries also experience more significant growth in manufacturing relative to services[6], thereby creating a larger productivity gap in manufacturing than in services. A larger productivity gap in a sector implies a greater potential for catch-up, hence a higher growth rate in that sector. In this context, if developing countries were integrating with countries in the industrialization phase, their level of industrialization would not shift prematurely as observed.

Fujiwara & Matsuyama (2022) employ a technology catch-up model that assumes countries differ in their ability to adopt frontier technology. They demonstrate that early deindustrialization can occur if technology adoption takes longer in the services sector compared to other sectors. In contrast, our model introduces credit constraints and reveals —without making the same assumptions— that technology adoption indeed takes longer in the services sector than in manufacturing and agriculture. This is due to the higher adjustment costs in services, given that this sector is more skill-intensive in terms of technology use. Moreover, we illustrate that the reality of developed countries being in a deindustrialization phase also contributes to a slower growth rate within the service sectors. This is primarily because the growth rate is positively associated with the technology gap relative to the frontier. This gap widens more rapidly in manufacturing than in services, thus influencing the rate of growth within these respective sectors.

This paper makes a distinct contribution to the field by introducing a nuanced model that underscores the differential impacts of financial development and technology adoption on structural transformation.

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[4]Considering that developed countries are undergoing deindustrialization, this implies that the growth rate in the manufacturing sector is higher than that in the services sector. Assuming that the growth rate in the manufacturing sector is higher than that in the services sector during the industrialization phase in the developing country, then when integration occurs, the technological frontier in the manufacturing sector will be relatively further ahead than that in the services sector.

[5]Important contributions include Ngai & Pissarides (2007), Herrendorf et al. (2021), Duarte & Restuccia (2010), Felipe & Mehta (2016), and Święcki (2017)

[6]This is due to the fact that earlier industrialized countries are in a phase of deindustrialization

While previous works have investigated the impact of trade integration and technological catch-up on deindustrialization, this paper adds depth to the understanding by introducing credit constraints into the model. It provides a unique perspective on how the phase of deindustrialization in developed countries can affect the growth rate in manufacturing and services in developing economies, a dynamic that previous models do not fully address. These novel insights make this paper a significant addition to the existing body of research on structural transformation.

Outline. The remainder of this paper is structured as follows: Section 2 presents empirical evidence on structural change and financial development, providing a backdrop against which the subsequent analysis is framed. In Section 3, the theoretical model is introduced, which captures the complex relationships between various factors driving structural transformation. Section 4 expounds upon the mechanisms by which technology adoption and financial development can influence structural transformation in developing countries. The paper concludes with Section 5, summarizing key insights and their implications.

2 Facts on Structural Change and Financial Development

In this section, we present the empirical facts and motivation that underpin the theoretical model using data from GGDC (Groningen Growth and Development Centre), Bolt & Van Zanden (2014), and IMF (2014).

2.1 Structural Change and Deindustrialization Across Countries

Kuznets' model of structural transformation presents two distinctive phases. Initially, during the early stages of development, the majority of a country's resources are dedicated to the agricultural sector. As the economy advances, resources gradually shift from agriculture to industry and services, marking the first phase of structural transformation—the industrialization phase. The second phase is characterized by a reallocation of resources away from both agriculture and industry toward the service sector—marking the deindustrialization phase.

Rodrik (2016) observes a trend in emerging economies where deindustrialization sets in at lower income levels and with lower peak manufacturing shares compared to early-industrialized advanced economies. This phenomenon, known as premature deindustrialization, appears more prominent in certain countries or regions.

Figure II below illustrates the evolution of labor share in manufacturing across different levels of development and by region. It distinguishes between Asia (represented in blue), Latin America (in green), and Africa (in dark red). We can see that the peak manufacturing share of African countries is lower than that of Latin American countries, which, in turn, is lower than the peak share in Asian countries. Furthermore, these peaks occur at sequentially lower levels of development, underscoring the manifestations of premature deindustrialization across regions.

In a comparative analysis between Latin America and East Asia, Ungor (2017) showed that the disparities in sectoral productivity growth rates substantially elucidate the unique sectoral reallocations observed in these two regions. Notably, this accounts for the slower transition of Latin America out of agriculture. Conversely, Huneeus & Rogerson (2023) employed a benchmark model of structural

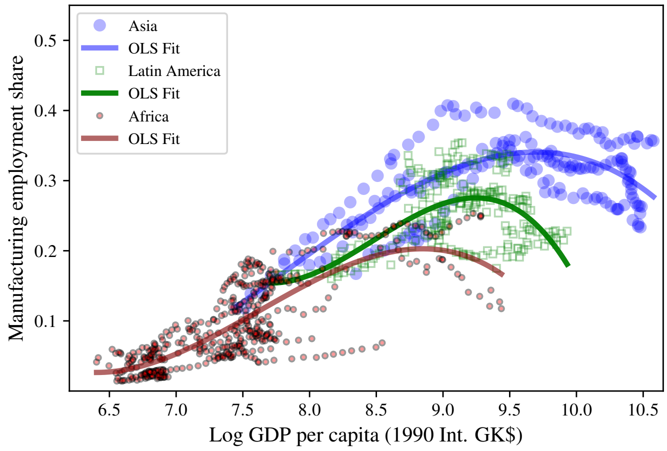


FIGURE II: Deindustrialization across regions, 1950-2010.

Note: The selection criteria dictate that the country should exhibit a well-defined hump in the manufacturing sector's employment share. Selected Asian economies include Japan, Korea, Malaysia, and Taiwan, while city-states such as Hong Kong and Singapore were excluded due to their negligible agricultural sectors despite having a pronounced hump-shape in manufacturing employment. Latin American selections encompass Argentina, Brazil, Chile, and Mexico. For Africa, South Africa and Mauritius are considered. Data sources : Timmer et al. (2015) and Bolt & Van Zanden (2014).

change, revealing that varied rates of catch-up in sectoral productivities among nations can lead to diverse industrialization trajectories, including instances of premature deindustrialization, as observed in empirical data. Given these findings, it becomes imperative to further investigate the factors underpinning the discrepancies in the progression of sectoral productivities across countries.

2.2 Financial Development and Sector-Biased Productivity Growth

Recent research on endogenous economic growth underscores that technological advancements predominantly occur within specific industries, leading to diverse rates of sector productivity growth (See Comin & Hobijn (2010), and Comin & Mestieri (2018) for example). As a result, countries that adeptly adopt new technologies within certain sectors may witness heightened productivity growth in those sectors. Next, we test whether the levels of financial development distinctly impact sectoral productivity growth rates or not.

Figure III illustrates the temporal evolution of the average level of financial development by regions, using data from the International Monetary Fund produced by Sahay et al. (2015). The figure reveals considerable differences in average financial development across regions or countries. While Western and Asian countries have experienced an increase over time, the African continent has not seen a substantial rise in its level of financial development. However, certain countries, such as South Africa, have seen a significant increase. For instance, South Africa's financial development level increased from 0.29 in the 1980s to 0.6 in 2010.

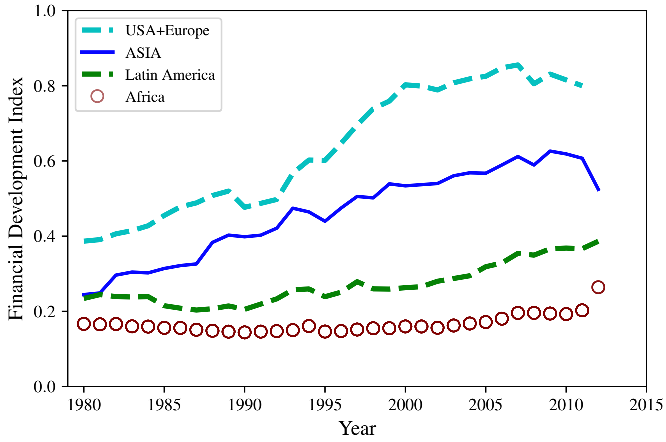


FIGURE III: Average financial development by region over time.

Comin & Nanda (2019) and Avoumatsodo (2023) demonstrated that financial development distinctly impacts the intensity of use of various adopted technologies. In a linear regression model, we examine whether the productivity growth in a sector within a country, and across different countries, might be influenced by the productivity level at the frontier. Furthermore, we investigate whether financial development exerts the same or differing influences on productivity growth across various sectors within the same country and between different countries. To do this we interact the level of financial development in a country with the levels of proximity to the frontier technology in the sectors of agriculture (a), manufacturing (m), and services (s). We use Equation (2.1) for this investigation:

$$g_{cj} = \eta_j + \rho_c + \beta_1 FD_{-1}^{c} + \beta_2 dist_{-1}^{jc} + \beta_3 \left(FD_{-1}^{c} \times dist_{-1}^{jc} \right) + \mu_{cj} \tag{2.1}$$

In this equation, g_{cj} signifies the average productivity growth in sector j (which can be either agriculture, manufacturing, or serces) for country c from the first decade to the last decade of the sample period, specifically between 1980-1990 and 2000-2010. For this analysis, a set of sector fixed effects, η_j, is incorporated into the regression specification to capture the unique attributes of each sector. Country-fixed effects, denoted by ρ_c, are also included to account for country-specific factors potentially influencing productivity growth.

The variable FD_{-1}^{c} represents the logarithm of the average measure of financial development of country c during 1980-1990. Meanwhile, $dist_{-1}^{cj}$ signifies a country's average proximity to the technological frontier in sector j during the same period. For this study, the United States serves as the benchmark for the technological frontier. The measure $dist_{-1}^{cj}$ is derived as the logarithm of the average productivity ratio between country c and the US in sector j for the 1980-1990 period, specifically $dist_{-1}^{cj} = \log(A_{-1}^{cj}) - \log(A_{-1}^{usj})$, where A_{-1}^{cj} (resp. A_{-1}^{usj})[7] indicates the average productivity of the country c (resp. US) between 1980 and 1990. This ratio offers a measure of country c's productivity in comparison to the frontier within the same sector during the 1980. And μ_{cj} is the residual or disturbance term.

Fundamentally, this regression model offers a comprehensive framework for examining whether disparities in financial development and sectoral productivity, relative to the technological frontier, might

[7] From GGDC database, we construct sectoral productivity levels in constant 2005 international US$ that are comparable across countries in the same year and over time.

contribute to variations in sectoral productivity growth across different sectors and countries. Table I presents the coefficients from various estimations results. Columns (1) through (3) represent the results from the baseline model, treating each observation as a distinct sector within a country. Meanwhile, columns (4) through (6) provide the results of separate cross-country regression analyses for each sector, specifically, agriculture, manufacturing, and services. The negative coefficient of β_2 suggests that

TABLE I: Regression results of productivity growth in various sectors

	Sectoral labor productivity growth					
	Baseline			Agri.	Manu.	Serv.
	(1)	(2)	(3)	(4)	(5)	(6)
$\beta_1 : FD_{-1}$	0.192	0.235	0.013	1.003	0.060	0.294**
	(0.357)	(0.152)	(0.951)	(0.453)	(0.639)	(0.013)
$\beta_2 : dist_{-1}$	-1.810*	-1.013*	-1.890*	-3.049*	-0.884***	-0.343*
	(0.089)	(0.079)	(0.083)	(0.094)	(0.001)	(0.052)
$\beta_3 : FD_{-1} \times dist_{-1}$	-0.688	-0.391	-0.798*	-1.027	-0.380***	-0.024
	(0.104)	(0.176)	(0.095)	(0.120)	(0.006)	(0.827)
Country FE		✓				
Sector FE			✓			
Observations	63	63	63	21	21	21
R-squared	0.308	0.479	0.345	0.437	0.765	0.823

***Notes*:** Ecarts-types robustes. Robust pvalues in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The data are aggregated into 10-year periods. Explanatory variables represent averages over the initial period (1980–1990), while the dependent variable is the sectoral productivity growth rate between the initial (1980–1990) and final (2000–2010) periods.

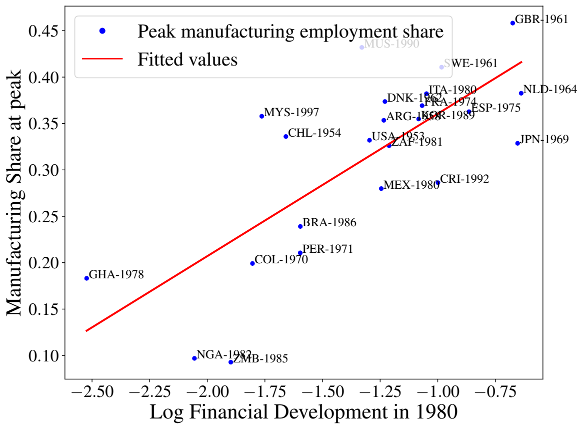
sectors that are farther away from the technological frontier may experience greater productivity growth. This could be due to the so-called "catch-up" mechanism, where sectors that initially lag behind have more room for productivity gains by adopting existing technologies and practices from more advanced economies. The interaction coefficient β_3 is negative, indicating that the effect of financial development on productivity growth could be more pronounced for sectors that are far from the frontier. While the p-value associated with this term is slightly above conventional levels of statistical significance, it is near enough to the 10% threshold to warrant further investigation. This result might suggest that financial development could have a particularly beneficial role in enhancing growth in sectors farther from the frontier, possibly by enabling more efficient adoption and utilization of existing technologies and practices. The greater the sector's distance from the frontier (i.e., the more negative the value of $dist_{-1}$), the more positive the impact of financial development (FD_{-1}) on productivity growth, due to the negative coefficient on the interaction term.

In summary, the regression models offer critical insights into how financial development and relative proximity to the technological frontier can differentially affect sectoral productivity growth across countries. Sectors further from the frontier, and thus possessing higher growth potential, may see a more pronounced productivity increase with elevated financial development. Therefore, the nation's financial development level could fuel structural transformation by expediting technology adoption and diffusion within these specific sectors. Next, we conduct a cross-sectional analysis to understand how variations in financial development levels across countries shape their structural change paths.

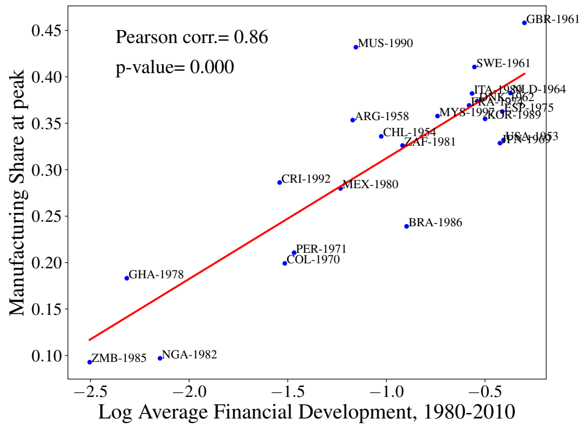
2.3 Financial Development and Structural Change : Cross-Country Analysis

In this subsection, we conduct a cross-country analysis to examinethe anticipated relationship between a country's level of financial development and its structural change. Indeed, the previous analysis suggest that we can expect countries with higher financial development to experience a rapid transition out of agriculture, a higher level of industrialization, and also a swifter shift towards services following the phase of industrialization, that is, after the peak in manufacturing.

Figure IV–(**b**) depicts manufacturing employment share at the peak of industrialization to the average level of financial development[8] over the period 1980-2010 (in log) to establish the correlation between financial development level and the level of industrialization in cross-section. As can be seen on the graph, the Pearson correlation is positively significant and equals 0.86, indicating that countries that have achieved a higher level of industrialization are the same ones with a high level of financial development over the period from 1980 to 2010. In order to ascertain whether this correlation significantly changes depending on the year considered for the level of financial development, Figure IV–(**a**) uses the level of financial development at the start of the period in 1980 rather than the average. The correlation does not appear to change significantly.



(a) Initial financial development



(b) Average financial development

FIGURE IV: Peak manufacturing employment share and financial development across countries.

In the following Table II, we present the results of the regression of the peak level of employment share in manufacturing on the average level of financial development, controlling for the average level of GDP, the population size, and the level of GDP corresponding to the peak in manufacturing. Despite the fact that we have only 23 country observations, we can still consider the statistical significance of the coefficients in light of the normality results for the error terms from the Shapiro-Wilk test.

The p-values from the Shapiro-Wilk test for skewness and kurtosis are above the 5% threshold, which leads us to conclude that we cannot reject the hypothesis of normality for the error terms. This result supports the robustness of the regression coefficients, given the assumption of normally distributed errors

[8] Ideally, data on financial development levels preceding the manufacturing peak would be utilized, but the IMF database on financial development levels we have at our disposal only covers the period from 1980 to 2014. However, only a majority of developed countries have reached the manufacturing peak before this period.

that underpins many statistical inferences in small sample scenarios. Consequently, we can consider the interpretation of the regression output and the substantial insights it provides regarding the relationship between the peak level of manufacturing employment share and financial development.

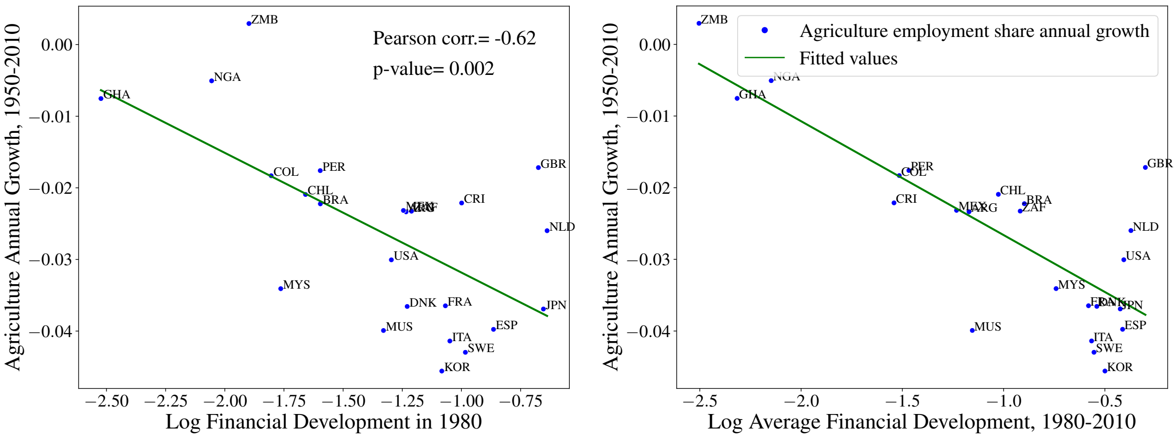
According to the estimates, the coefficient of the financial development level is both positive and significant. This lends support to the assertion that financial development intensifies structural change, particularly by promoting industrialization during the industrialization phase. We conduct the same

TABLE II: Cross-country regression of peak manufacturing employment share

	Manufacturing employment share at the peak			
	(1)	(2)	(3)	(4)
Log average financial development	0.130***	0.072*	0.116***	0.095**
	(0.015)	(0.039)	(0.028)	(0.037)
Log average gdp per capita		0.049	0.024	
		(0.032)	(0.020)	
Log average population			-0.028***	-0.026***
			(0.007)	(0.006)
Log gdp per capita at the peak				0.044
				(0.026)
Nb. of countries	23	23	23	23
R-squared	0.73	0.75	0.87	0.88
Pvalue of Shapiro-Wilk test	0.13	0.16	0.47	0.28

Ecarts-types robustes. Robust standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

analysis for the agricultural sector by examining the correlation between the rate of decrease in employment share in the agricultural sector and the level of financial development. Figure V depicts the average annual growth rate over the entire period for which data are available for each country from 1950 to 2010, and the average level of financial development over the period from 1980 to 2010. We can observe a negative correlation, which means that the countries exhibiting a substantial transition out of the agricultural sector are the ones that had a higher average level of financial development. Table III presents the results of estimates for the average annual growth rate of employment in the agricultural sector in a country, relative to the country's average level of financial development. In a cross-sectional perspective, we can again observe that countries with a higher level of financial development have undergone a more substantial structural transition out of the agricultural sector. This once again supports the model's prediction, which posits that an increase in the level of financial development will impact the reduction of employment share in the agricultural sector.



(a) Initial financial development

(b) Average financial development

FIGURE V: Exit rate from the agricultural sector and financial development.

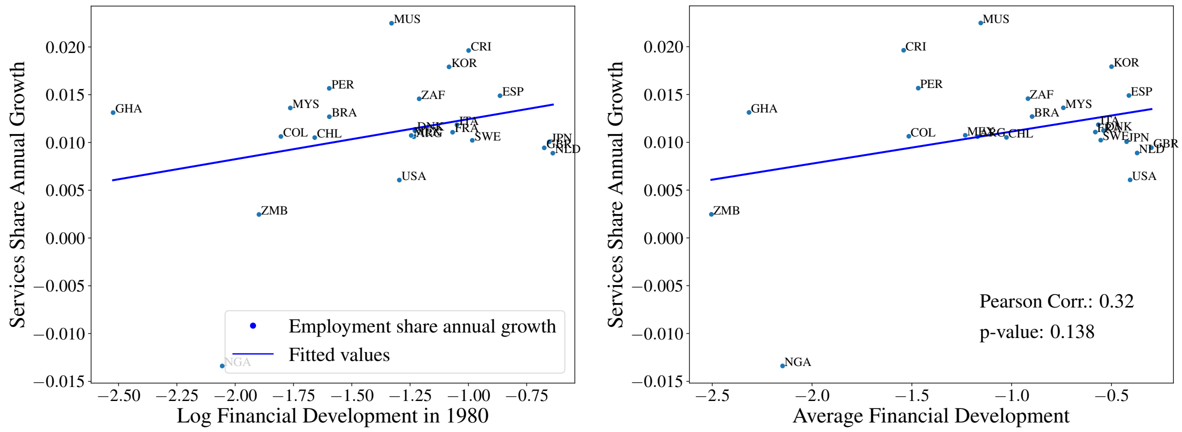
TABLE III: Cross-country regression of annual growth of agriculture employment share

	Annual decrease in agriculture labor share		
	(1)	(2)	(3)
Log average financial development	-0.016***	-0.014*	-0.018***
	(0.002)	(0.007)	(0.006)
Log average gdp per capita		-0.002	0.001
		(0.005)	(0.004)
Log average population			0.003**
			(0.001)
Nb. of countries	23	23	23
R-squared	0.64	0.65	0.71
Pvalue of Shapiro-Wilk test	0.16	0.17	0.04

Ecarts-types robustes. Robust standard errors in parentheses.
** p<0.01, ** p<0.05, * p<0.1

As with the other sectors, we test whether the level of financial development will have a positive impact on the increase in services during the deindustrialization phase. For this, we consider the average annual growth rate of employment share in the services sector over the period between the peak year in manufacturing and 2010. Figure VI depicts the correlation between this average annual growth rate and the average level of financial development. Contrary to the agricultural and manufacturing sectors, even though the correlation is positiveit is not significant. The difference observed in services can be attributed to the early deindustrialization seen in many developing countries. Some of these countries have transitioned into the service sector without undergoing a significant manufacturing phase, leading to a shift into services even when the level of financial development is relatively low. This premature entry into the service sector is driven not by financial development, but rather by globalization, which results in higher productivity growth in manufacturing compared to services. This phenomenon is referred to by Lewis et al. (2021) as the importation of sector-biased productivity growth from other countries.

However, while their model provides valuable insights, it does not adequately explain why integra-



(a) Initial financial development

(b) Average financial development

FIGURE VI: Services employment share average annual growth between 2010 and the year of peak in manufacturing.

tion with developed countries has distinct impacts on different sectors of economic activities, or which sectors are likely to experience higher growth rates. To address this gap, the following section presents a three-sector endogenous growth model that examines the effects of financial development and globalization on a country's structural change over time, particularly through the lens of technology adoption.

3 Theoretical Framework

The economy consists of three final goods sectors: agriculture (a), manufacturing (m), and services (s). Each sector produces a distinct final good in a competitive market using labor and a sector-specific intermediate input. Time is discrete, and at each period t, there is a mass L_t of individuals. Each individual is endowed with one unit of labor, which she supplies inelastically to final goods production. Additionally, individuals can invest in technology adoption projects as entrepreneurs. Structural change in the model is driven by time-varying, country-specific sectoral productivity growth—shaped by the intensity of new technology adoption—and by nonhomothetic preferences.

3.1 Goods Production Sectors

Final Goods Production. Each final good is produced using labor and a sector-specific intermediate input according to a Cobb-Douglas production function:

$$Y_{kt} = (A_{kt}L_{kt})^{1-\alpha} x_{kt}^{\alpha} \quad \forall k \in a, m, s, \tag{3.1}$$

where $0 < \alpha < 1$, A_{kt} denotes the sector k productivity level at time t, x_{kt} is the quantity of input of the intermediate good, and L_{kt} is the amount of labor employed in sector k. The productivity term A_{kt} will be endogenized in Section 3.2, where it is derived as a function of technology adoption dynamics. Since final goods sectors are competitive, each representative firm takes the output price P_{kt} and the intermediate input price p_{kt}^{x} as given, and chooses labor L_{kt} and intermediate input x_{kt} to maximize profits. The corresponding first-order conditions imply:

$$x_{kt} = \alpha^{\frac{1}{1-\alpha}} \left(\frac{p^x_{kt}}{P_{kt}}\right)^{-\frac{1}{1-\alpha}} A_{kt} L_{kt} \tag{3.2}$$

$$w_t = (1-\alpha) P_{kt} L_{kt}^{-\alpha} A_{kt}^{1-\alpha} x_{kt}^{\alpha}, \tag{3.3}$$

where w_t is the wage rate.

Intermediate Goods Production. At the beginning of each period, one individual in each sector successfully adopts the latest available technology from the global frontier and implements it in the most efficient way. This entrepreneur becomes the most productive in her sector and, as a result, gains a temporary monopoly over the production of the corresponding intermediate good.

Intermediate goods are produced one-for-one using the final good of the same sector: producing one unit of the intermediate input for sector k requires one unit of the final good k. Given her monopoly status, the entrepreneur sets the price of the intermediate good to maximize profit, taking into account the demand function derived from the final goods producer's optimization problem. It maximizes its profit as follows:

$$\max_{\{p^x_{kt}\}} \Pi_{kt} = p^x_{kt} x_{kt} - P_{kt} x_{kt} \tag{3.4}$$

$$\text{s.t.} \qquad x_{kt} = \alpha^{\frac{1}{1-\alpha}} \left(\frac{p^x_{kt}}{P_{kt}}\right)^{-\frac{1}{1-\alpha}} A_{kt} L_{kt} \tag{3.5}$$

The first-order condition of this problem implies that the equilibrium quantity of the intermediate good in sector k is given by:

$$x_{kt} = \alpha^{\frac{2}{1-\alpha}} A_{kt} L_{kt} \tag{3.6}$$

at the expression of optimal price p^x_{kt} is:

$$p^x_{kt} = \alpha^{-1} P_{kt}.$$

The profit earned by the intermediate good monopolist in sector k at time t is given in equilibrium by:

$$\Pi_{kt} = \pi P_{kt} A_{kt} L_{kt}, \tag{3.7}$$

where $\pi := (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}$ is a constant determined by the production parameter α.

Profits in each intermediate sector are positively related to sectoral productivity, A_{kt}, labor employed in the sector, L_{kt}, and the final good price, P_{kt}. An increase in the output price P_{kt} raises the demand price for intermediate inputs in sector k, thereby increasing monopolist revenue. Similarly, greater labor input boosts final output, which raises the quantity of intermediate inputs demanded, as implied by the Cobb-Douglas production structure.

The production level of the final good k at equilibrium is obtained by substituting Equation (3.6) in

Equation (3.1):

$$Y_{kt} = \alpha^{\frac{2\alpha}{1-\alpha}} A_{kt} L_{kt} \tag{3.8}$$

and the wage rate from (3.3) is given by :

$$w_t = \omega P_{kt} A_{kt}, \tag{3.9}$$

where $\omega := (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}$.

Let's denote VA_{kt} and GDP_t the value added of the sector k the gross domestic production of the economy at the period t. Their expressions at the equilibrium are:

$$\begin{aligned} VA_{kt} &= \zeta P_{kt} A_{kt} L_{kt} && (3.10) \\ GDP_t &= (1+\alpha) w_t L_t && (3.11) \end{aligned}$$

where $\zeta := (1-\alpha^2)\alpha^{\frac{2\alpha}{1-\alpha}}$. See Apendix A.1.2 for derivations.

3.2 Technology Adoption and Productivity Growth

Productivity grows as a result of technology adoption, which enables sectoral monopolists to access the global technology frontier in sector k. At the end of each period t, entrepreneurs initiate technology adoption projects for use in the following period. A key and novel contribution of this study is that it focuses not on modeling the process of technology adoption itself, but rather on examining the effective utilization of adopted technologies.

While prior research—such as Comin & Mestieri (2018)—has shown that most countries have successfully adopted a wide range of technologies, the distinguishing factor lies in how intensively these technologies are used across sectors. This paper builds on that insight by emphasizing variation in the intensity of use as a driver of cross-country productivity differences.

Let θ_{kt} denote the intensity with which technologies are used in sector k at time t. Then, a country's productivity in sector k evolves as a function of the intensity of technology use at the frontier, such that:

$$A_{kt} = \theta_{kt}\bar{A}_{kt-1} + (1-\theta_{kt})A_{kt-1}, \quad k = a, m, s \tag{3.12}$$

where $\bar{A}_{kt-1}$ is the productivity of the frontier in sector at time $t-1$. The expansion of this productivity is exogenous and results in innovation. We denote by $\bar{g}_k$ the growth rate of sectoral productivity at the frontier in the sector k.

We follow the approach of Aghion et al. (2005) to model technology adoption, adapting it to the sectoral level. In our framework, technology adoption in each sector is carried out through investments made using that sector's final good. Specifically, if Z_{kt} units of final good k are allocated to technology adoption in sector k at time $t-1$, the resulting intensity of technology usage, denoted by θ_{kt}, is realized at time t and is governed by the following relationship:

$$\frac{Z_{kt}}{\bar{A}_{kt-1}} = \phi_k F(\theta_{kt}), \quad F' > 0,\ F'' > 0,\ F(0) = 0, \text{ and } \phi_k > 0 \tag{3.13}$$

where $Z_{kt}/\bar{A}_{kt-1}$ is productivity-adjusted technology adoption expenditure in the sector k. The total investment Z_{kt} in sector k is divided by $\bar{A}_{kt-1}$, the targeted productivity parameter, to take into account the "fishing-out" effect[9]. The parameter ϕ_k captures the cost-efficiency of adopting technology in sector k. It reflects how easily a sector can absorb and implement technology, given the required inputs, skills, and sectoral constraints. A higher ϕ_k indicates that technology adoption is more expensive per unit of intensity θ_{kt}, suggesting higher barriers to adoption. Conversely, a lower ϕ_k suggests that technology can be adopted more efficiently and at a lower cost.

Sectors vary substantially in the level of skills, knowledge, and expertise required to implement new technologies, and this heterogeneity is reflected in ϕ_k. For instance, the services sector often requires a highly specialized and skilled workforce to adopt and operate technologies such as telecommunications, computer systems, and financial services infrastructure. The scarcity or high cost of such skilled labor can raise the value of ϕ_k, making technology adoption more expensive.

In contrast, technology adoption in agriculture tends to involve less specialization, with innovations often centered around mechanization, irrigation systems, or fertilizers—technologies that require less technical expertise. Consequently, ϕ_k in agriculture can be relatively lower, making technology adoption less costly relative to sectors with higher skill demands. These differences imply that sectors with greater human capital requirements or more complex technological needs will adopt new technologies more slowly, leading to delayed productivity gains.

Since the function F is convex, the amount of investment Z_{kt} in technology adoption increases with the level of targeted intensity of technology usage θ_{kt}. At equilibrium an entrepreneur chooses Z_{kt} (or chooses θ_{kt}) in order to maximize his net payoff given by :

$$\Pi_{kt} - P_{kt-1}Z_{kt} \tag{3.14}$$

The amount $P_{kt-1}Z_{kt}$ invested at time $t-1$ in technology adoption projects is borrowed and we assume that there is a presence of credit constraints so that $P_{kt-1}Z_{kt}$ is constrained by a certain amount depending on the level of financial development of the country. That is, the entrepreneur cannot borrow more than a finite multiple of country's GDP per capita:

$$P_{kt-1}Z_{kt} \leq \kappa_{t-1} GDP_{t-1} \tag{3.15}$$

where κ_{t-1} is the level of financial development of the country at period $t-1$. Entrepreneurs in less financially developed countries face more pronounced constraints, where the impact of these constraints is particularly significant for certain technologies, especially those in more productive sectors. The presence of credit constraints will tend to limit the adoption and the intensity of technology usage.

By substituting equation (3.7) into equation (3.14) one gets a maximization problem in the intensity of using the new technologies:

$$\max_{\theta_{kt}} \ \pi P_{kt}\left[\theta_{kt}\bar{A}_{kt-1} + (1-\theta_{kt})A_{kt-1}\right]L_{kt} - P_{kt-1}\phi_k F(\theta_{kt})\bar{A}_{kt-1} \tag{3.16a}$$

$$s.t. \qquad \theta_{kt} \leq F^{-1}\left(\frac{\zeta\kappa_{t-1}a_{kt-1}}{\phi_k}\right), \tag{3.16b}$$

[9] The further the technological frontier is, the more expensive it will be to catch up with it.

where the parameters ϕ_k, $k = a, m, s$ are such[10] that the intensity of use of adopted technologies is less than one, i.e., $0 \leq \theta_{kt} \leq 1$. The Inequality (3.16b) is derived by applying the credit constraint defined in Inequality (3.15), and by combining Equation (3.13) with Equation (3.11).

As in Aghion & Howitt (1992), we assume that the convex cost of investment in the technological adoption function F takes the form:

$$F(\theta_{kt}) = \theta_{kt}^2 \tag{3.17}$$

Let us denote by $\hat{\theta}_{kt}$ the intensity of technology use in the presence of perfect credit markets in sector k at time t (without the credit constraint 3.16b). Solving the problem (3.16a) yields:

$$\hat{\theta}_{kt} = \min\left\{1;\ \frac{\pi P_{kt}(1 - a_{kt-1})L_{kt}}{2\phi_k P_{kt-1}}\right\} \tag{3.18}$$

where $a_{kt-1} := A_{kt-1}/\bar{A}_{kt-1}$ is the sectoral proximity to the technology frontier at time $t-1$ in sector k.

Equation (3.18) shows that under perfect credit markets, an increase in labor demand and the growth rate of output prices in a sector raises the incentive for intermediate goods producers to adopt more technologies. This is because the expected returns from adopting these technologies are expected to increase, strengthening the motivation for their utilization. However, $\hat{\theta}_{kt}$ decreases as the country approaches the technological frontier a_{kt-1}. Therefore, in theory, countries farther from the frontier should adopt and utilize existing technologies more intensively than countries closer to the frontier if perfect financial markets were present. This intensified usage would allow them to bridge the gap and catch up with advanced countries. In practice, however, this scenario fails to materialize due to the constraints that hinder the adoption of more advanced technologies, limiting the ability of developing countries to fully exploit existing technological opportunities.

The expression of intensity of use of technology θ_{kt}^* at equilibrium, in the presence of imperfections in the credit market (when the credit constraint 3.16b is binding), is given by:

$$\theta_{kt}^* = \left(\frac{\zeta \kappa_{t-1} a_{kt-1}}{\phi_k}\right)^{1/2} \tag{3.19}$$

This equation shows that θ_{kt}^* will be higher for countries with greater financial development. Additionally, countries closer to the technological frontier will experience a higher intensity of technology use compared to countries further away contrary to the case of perfection of the financial markets, even at the same level of financial development.

Imperfections in the credit market create a constraint that limits entrepreneurs from using technologies more intensively, and this effect is well-documented in the literature. Credit constraints are particularly prevalent in developing countries, and various authors, such as Banerjee & Duflo (2005), Aghion et al. (2005), and Cole et al. (2016) have demonstrated how this issue significantly hampers technology adoption. To be consistent with these facts, we assume the following relation for developing countries[11]:

$$\theta_{kt}^* \leq \hat{\theta}_{kt}. \tag{3.20}$$

[10] A country's sectoral productivity is assumed to be less than the frontier productivity, which is where it sources new technological ideas.

[11] This relationship is plausible and will hold in the vast majority of cases. Indeed, the presence of a large and increasing number of workers L_{kt} in the expression for $\hat{\theta}_{kt}$ typically drives its final value to 1. Moreover, the model parameters are such that $0 \leq \theta_{kt}^* \leq 1$. As a result, the relationship $\theta_{kt}^* \leq \hat{\theta}_{kt}$ will generally be satisfied.

In the remainder of the paper, unless otherwise stated, we focus on the case of economies with credit market imperfections—that is, cases in which the intensity of technology use in sector k is given by θ^*_{kt}. The productivity growth rate g_{kt} of the sector k is therefore determined by :

$$g_{kt} = \theta^*_{kt}\left(a^{-1}_{kt-1} - 1\right) \tag{3.21}$$

The productivity growth rate g_{kt} decreases with the proximity in the presence of imperfections in the credit market[12]. The productivity growth in sectors that are near the technological frontier is expected to be slower compared to sectors that are further away from it. This implies that the level of advancement of each sector at the frontier can influence the process of structural change in developing countries.

3.3 Households

Each period a household receives instantaneous utility $\log C_t$ from its consumption bundle, where C_t is the level of aggregate consumption, which is a function of sectoral consumption C_{kt}, $k = a, m, s$. Borrowing from Comin et al. (2021), the real consumption index $\{C_t\}$ is described by an implicit function defined by the following nonhomothetic CES aggregator:

$$\sum_{k=a,m,s} \delta_k^{1/\sigma}\left(\frac{C_{kt}}{C_t^{\varepsilon_k}}\right)^{\frac{\sigma-1}{\sigma}} = 1 \tag{3.22}$$

where δ_k are constant weights for each sector in the economy and sum to one. The parameter signal σ is the elasticity of substitution between goods. $\sigma < 1$ such that agricultural and manufacturing goods and services are complements. ε_k define the relative Engel curve for each sectoral output k, and represents the income elasticity of demand of sector k. We opt for the expression of this preference rather than a Stone-Geary preference because Comin et al. (2021) show that this specification of nonhomothetic CES preferences has attractive properties for studying long-run structural change.

In each period, given the nonhomothetic CES aggregator (3.22), the representative household maximizes its utility, in each period by choosing sectoral consumption levels, C_{kt}, as follow:

$$\max_{\{C_{at}, C_{mt}, C_{st}\}} \log C_t \tag{3.23}$$

$$\text{s.t.} \qquad \sum_{k\in\{a,m,s\}} P_{kt}\left(C_{kt} + Z_{kt+1}\right) \leq w_t L_t + \sum_{k=a,m,s} \Pi_{kt}$$

where Π_{kt} is the profit of the monopolist producer of intermediate goods in sector k. This utility maximization problem (3.23) is equivalent to total expenditure (on consumption in agriculture, manufacturing and services) minimization problem subject to the implicit CES nonhomothetic aggregator.

Given the nonhomothetic CES aggregator, the intra-temporal household's problem is equivalent to

[12] Note that the logarithm function is lower and increases faster than the first bisector on the intervall [0, 1] so that g_{kt} decreases with a_{kt-1}.

the expenditure minimization problem below[13]:

$$\min_{\{C_{at},C_{mt},C_{st}\}} \sum_{k=a,m,s} P_{kt}C_{kt} \tag{3.24}$$

$$\text{s.t.} \qquad \sum_{k=a,m,s} \delta_k^{1/\sigma} \left(\frac{C_{kt}}{C_t^{\varepsilon_k}}\right)^{\frac{\sigma-1}{\sigma}} = 1 \tag{3.25}$$

The first-order conditions imply that sectoral consumption demand satisfies:

$$C_{kt} = \delta_k \left(\frac{P_{kt}}{E_t}\right)^{-\sigma} C_t^{\varepsilon_k(1-\sigma)} \tag{3.26}$$

where $E_t := \sum_{k=a,m,s} P_{kt}C_{kt}$ is the total expenditure in consumption at time t. See Appendix A.1.1 for calculation.

Equation (3.26) can be rewritten as:

$$C_{kt} = \delta_k \left(\frac{P_{kt}}{P_t}\right)^{-\sigma} C_t^{\varepsilon_k(1-\sigma)+\sigma} \tag{3.27}$$

where P_t is the price index in the economy at the period t which the expression is[14]:

$$P_t = \left[\sum_{k=a,m,s} \delta_k P_{kt}^{1-\sigma} C_t^{(1-\sigma)(\varepsilon_k-1)}\right]^{\frac{1}{1-\sigma}} \tag{3.28}$$

3.4 Equilibrium

The timing of the model can be summarized as follows:

Step 0 : Period t starts with a productivity, A_{kt}, $k = a, m, s$, result of investment in adoption of new technologies;

Step 1: The production of intermediate goods then that of final goods take place;

Step 2: Entrepreneurs choose the optimal amount Z_{kt+1}—equivalent to the optimal intensity of technology use, θ_{kt+1}—to invest in a technology adoption project in each sector $k \in a, m, s$ for the next period.

Step 3: Households choose the levels of consumption of sectoral final goods.

The model economy is summarized by time-invariant parameters $\{\alpha, \sigma, \delta_a, \delta_m, \delta_s\}$, the initial sectoral productivity A_{k0}, and time-varying exogenous processes of frontier sectoral productivities, total labor force, and the country's financial development level $\{\bar{A}_{kt}, L_t, \kappa_t\}$.

Definition. An equilibrium is a collection of wage and prices of final goods $\mathbf{p} = \{w_t, P_{at}, P_{mt}, P_{st}\}_{t=0}^{\infty}$; consumption allocation decisions $\mathbf{c} = \left\{C_{at}, C_{mt}, C_{st}\right\}_{t=0}^{\infty}$ for the household; labor and intermediate inputs allocation decisions $\mathbf{f} = \left\{L_{kt}, x_{kt}\right\}_{t=0\,;k=a,m,s}^{\infty}$ for firms in final sectors; and collection of decisions $\mathbf{z} = \{Z_{at}, Z_{mt}, Z_{st}\}_{t=1}^{\infty}$ and $\mathbf{p}^x = \{p_{at}^x, p_{mt}^x, p_{st}^x\}_{t=0}^{\infty}$ for producers of intermediate varieties such that:

- Given $\mathbf{p}$, households solve the problem (3.23) ;

[13] The expenditure minimization problem is the dual of the utility maximization problem. The relationship between the utility function and Marshallian demand in the utility maximization problem mirrors the relationship between the expenditure function and Hicksian demand in the expenditure minimization problem.

[14] See Appendix A.1.1 for the demonstration.

- Given $\mathbf{p}$ and $\mathbf{p}^x$, final goods producers maximize their profit;
- Given $\mathbf{p}$, intermediate input producers maximize (3.4) and (3.16a);

and labor and good markets are cleared.

Market Clearing Conditions. The factor market clearing conditions for labor and sectoral composite goods in each period are as follows:

$$L_t = L_{at} + L_{mt} + L_{st} \tag{3.29}$$

$$Y_{kt} = C_{kt} + X_{kt} + Z_{kt+1}. \tag{3.30}$$

Table IV collects all conditions that fully characterize the equilibrium of the model.

TABLE IV: Equilibrium Conditions

$D_1:$	$C_{kt} = \delta_k \left(\frac{P_{kt}}{P_t}\right)^{-\sigma} C_t^{\varepsilon_k(1-\sigma)+\sigma}$	$\forall k = a,m,s$
$D_2:$	$\sum_{k\in\{a,m,s\}} P_{kt}\left(C_{kt} + Z_{kt+1}\right) = w_t L_t + \sum_{k=a,m,s} \Pi_{kt}$	
$D_3:$	$P_t C_t = \sum_{i=a,m,s} P_{it} C_{it}$	
$D_4:$	$P_t = \left[\sum_{k=a,m,s} \delta_k P_{kt}^{1-\sigma} C_t^{(1-\sigma)(\varepsilon_k-1)}\right]^{\frac{1}{1-\sigma}}$	
$S_1:$	$X_{kt} = \alpha^{\frac{2}{1-\alpha}} A_{kt} L_{kt}$	$\forall k = a,m,s$
$S_2:$	$Y_{kt} = \alpha^{\frac{2\alpha}{1-\alpha}} A_{kt} L_{kt}$	$\forall k = a,m,s$
$S_3:$	$w_t = \omega P_{kt} A_{kt}$	$\forall k = a,m,s$
$S_4:$	$Z_{kt} = \phi_k \theta_{kt}^2 \bar{A}_{kt-1}$	$\forall k = a,m,s$
$S_5:$	$\Pi_{kt} = \pi P_{kt} A_{kt} L_{kt}$	$\forall k = a,m,s$
$S_6:$	$\frac{A_{kt+1}}{A_{kt}} = \theta_{kt}^* \left[a_{kt-1}^{-1} + 1\right] + 1$	$\forall k = a,m,s$
$S_7:$	$\theta_{kt}^* = \left(\frac{\zeta \kappa_{t-1} a_{kt-1}}{\phi_k}\right)^{1/2}$	$\forall k = a,m,s$
$G_1:$	$L_{at} + L_{mt} + L_{st} = L_t$	
$G_2:$	$Y_{kt} = C_{kt} + X_{kt} + Z_{kt+1}$	$\forall k = a,m,s$

4 Theoretical Analysis

In this section, we provide a theoretical analysis of the roles of technology adoption and financial development in driving structural transformation. We begin by outlining how structural transformation is measured within our framework.

4.1 Definition of Structural Transformation

We measure structural transformation using sectoral expenditure shares. Let $e_{kt} = P_{kt}C_{kt}/P_tC_t$ denote the expenditure share of sector k in period t. Using Equation (3.27) we can derive the following expression for the sectoral share of consumption expenditure in good k:

$$e_{kt} = \delta_k \left(\frac{P_{kt}}{P_t}\right)^{1-\sigma} C_t^{(1-\sigma)(\varepsilon_k-1)} \qquad k = a,m,s. \tag{4.1}$$

From Equation (4.1) we can obtain the ratio of consumption expenditure shares in sector k and manufacturing sector m as follow:

$$\frac{e_{kt}}{e_{mt}} = \frac{\delta_k}{\delta_m}\left(\frac{P_{kt}}{P_{mt}}\right)^{1-\sigma} C_t^{(\varepsilon_k-\varepsilon_m)(1-\sigma)} \qquad k = a,s. \tag{4.2}$$

Next, we will analyze the dynamics of consumption expenditure share ratios over time by considering the influence of the Engel effect and the Baumol effect. Additionally, we will explore how sectoral proximity can impact the process of structural change through technology adoption.

Since the wage rate w_t is the same across sectors, we can deduce from Equation (3.9) a relationship between relative sectoral prices and relative sectoral productivities as expressed by the following equality:

$$\frac{P_{kt}}{P_{mt}} = \frac{A_{mt}}{A_{kt}} \quad \forall k = a,s. \tag{4.3}$$

Using Equation (4.3), the ratio of consumption expenditure shares in Equation (4.2) can now be expressed as a function of the sectoral productivities, $\{A_{it}\}_{i=a,m,s}$ and the aggregate consumption C_t:

$$\frac{e_{kt}}{e_{mt}} = \frac{\delta_k}{\delta_m}\left(\frac{A_{mt}}{A_{kt}}\right)^{1-\sigma} C_t^{(\varepsilon_k-\varepsilon_m)(1-\sigma)} \quad \forall k = a,s. \tag{4.4}$$

Equation (4.4) illustrates both the supply- and demand-side mechanisms of structural transformation in our model. This implies the following recurrence equation, expressed in terms of changes in relative expenditure shares:

$$\frac{\Psi_{kt}}{\Psi_{kt-1}} = \underbrace{\left(\frac{1+g_{mt}}{1+g_{kt}}\right)^{1-\sigma}}_{\text{Baumol Effect}} \times \underbrace{\left(1+g_t\right)^{(1-\sigma)(\varepsilon_k-\varepsilon_m)}}_{\text{Engel Effect}}, \quad \forall k = a,s \tag{4.5}$$

where $\Psi_{kt} = e_{kt}/e_{mt}$ and g_t is the growth rate of the aggregate consumption between periods $t-1$ and t. Equation (4.5) decomposes the evolution of relative sectoral expenditures into two components. The first captures the Baumol effect and is related to differential productivity growth combined with a non-unitary elasticity of substitution between sectoral goods. As $\sigma \neq 1$, the ratio e_{kt}/e_{mt} is decreasing if $(1+g_{kt}) > (1+g_{mt})(1+g_t)^{\varepsilon_k-\varepsilon_m}$ and increasing if $(1+g_{kt}) < (1+g_{mt})(1+g_t)^{\varepsilon_k-\varepsilon_m}$. That is, sectoral consumption expenditure shares shift from sectors with faster productivity growth to those with slower productivity growth over time. The second component captures the income effect. As aggregate consumption increases, if goods are complements, the relative level of income elasticity in sector k, ε_k, compared to that of manufacturing, ε_m, influences changes in the consumption expenditure share allocated to sector k goods. When $\varepsilon_k - \varepsilon_m > 0$, the relative expenditure share of sector k rises with aggregate consumption; conversely, it declines when the inequality is reversed.

4.2 Technology Adoption and Structural Transformation

We begin with a static comparative perspective to illustrate how sectoral proximity to the technological frontier shapes structural transformation. Recall that in our framework, proximity is measured by the ration of productivities between a given sector in a country and the corresponding global frontier. Sectors that are further from the frontier (i.e., with lower proximity) have greater potential to experience faster productivity growth. This implies that structural transformation can be driven by differences in sectoral distances to the frontier.

We define the relative productivity growth rate of sector $k \in \{a,s\}$ compared to manufacturing as: $G_{kt} = (1+g_{mt})/(1+g_{st})$. Using the expressions for technology adoption and productivity dynamics from Equations (3.19) and (3.21), this ratio becomes:

$$G_{kt} = \frac{1+\left(\frac{\zeta\kappa_{t-1}a_{mt-1}}{\phi_m}\right)^{1/2}(a_{mt-1}^{-1}-1)}{1+\left(\frac{\zeta\kappa_{t-1}a_{kt-1}}{\phi_k}\right)^{1/2}(a_{kt-1}^{-1}-1)}\ , \quad \forall k = a,s. \tag{4.6}$$

This expression shows how relative productivity growth depends on sectoral proximity to the frontier and on the efficiency of technological adoption. Equation (4.5) then becomes:

$$\frac{\Psi_{kt}}{\Psi_{kt-1}} = G_{kt}^{1-\sigma} \times (1+g_t)^{(1-\sigma)(\varepsilon_k-\varepsilon_m)}\ , \quad \forall k = a,s. \tag{4.7}$$

To deliver the results transparently, we abstract from the Engel effect, driven by income changest—assuming $\varepsilon_a = \varepsilon_m = \varepsilon_s$. We focus on the Baumol effect, which is directly influenced by technology adoption and financial development, and has been identified in the literature as the primary quantitative driver of structural transformation.

$$\frac{\Psi_{kt}}{\Psi_{kt-1}} = \left[\frac{1+\left(\frac{\zeta\kappa_{t-1}a_{mt-1}}{\phi_m}\right)^{1/2}(a_{mt-1}^{-1}-1)}{1+\left(\frac{\zeta\kappa_{t-1}a_{kt-1}}{\phi_k}\right)^{1/2}(a_{kt-1}^{-1}-1)}\right]^{1-\sigma} \quad \text{for } \varepsilon_k = \varepsilon_m\ , \ \forall k = a,s. \tag{4.8}$$

The relationship in Equation (4.8) highlights how differences in sectoral proximity to the frontier drive changes in relative productivity growth rates and, consequently, the reallocation of resources across sectors. When adoption parameters are equal across sectors (i.e., $\phi_k = \phi_m$), a sector $k \in \{a,s\}$ that is closer to the frontier than manufacturing (meaning $a_{kt} > a_{mt}$) will exhibit lower relative productivity growth, and thus $G_{kt} > 1$, which implies a shift of resources toward sector k relative to sector m. Conversely, if sector k is further from the frontier, i.e., $a_{kt} < a_{mt}$, it has more room for catch-up through technology adoption, leading to faster productivity growth relative to manufacturing, which implies $G_{kt} < 1$.

However, when $\phi_k \neq \phi_m$, the rate of relative productivity growth is additionally influenced by the efficiency of technology adoption. A sector characterized by a significant technology gap may not experience accelerated growth if its adoption efficiency is sufficiently low. Consequently, both the sector's proximity to the technological frontier and its sector-specific adoption efficiency jointly determine the dynamics of relative productivity growth and, by extension, the process of structural transformation. In cases where proximity to the frontier is equal across sectors, a sector with a higher adoption parameter ($\phi_k > \phi_m$) will display slower relative productivity growth, resulting in $G_{kt} > 1$, accompanied by an increase in its share of consumption expenditure.

Generally, dynamics in sectoral proximties in a country affects structural transformation thourgh G_{kt}. The total differential dG_k of the function $G_k(a_m, a_k)$ following a variation in sectoral proximities a_m and a_k is given by Equation (4.9). The time subscript is omitted for clarity, unless explicitly required.

$$dG_k = \frac{(\zeta\kappa)^{1/2}}{2(1+g_k)}\left[\left(\frac{a_k}{\phi_k}\right)^{1/2}\left(a_k^{-1}+1\right)G_k\frac{da_k}{a_k} - \left(\frac{a_m}{\phi_m}\right)^{1/2}\left(a_m^{-1}+1\right)\frac{da_m}{a_m}\right] \tag{4.9}$$

Two straightforward results follow from Equation (4.9). First, when sector k becomes less proximate to the technological frontier ($da_k < 0$) while manufacturing becomes more proximate ($da_m > 0$), the relative productivity growth G_k declines. Consequently, from Equation (4.7), the relative growth of consumption expenditure on sector k also decreases. Second, if sector k becomes closer to the frontier ($da_k > 0$) while manufacturing moves further away ($da_m < 0$), then G_k increases, leading to a higher growth rate in the relative consumption expenditure of sector k.

In cases where the previous two conditions are not met—such as when sectoral proximity increases or decreases simultaneously across sectors, or when changes are of uneven magnitude—the impact on relative productivity growth G_k is no longer straightforward. The final outcome hinges on the interaction between model parameters, the relative scale of changes in proximity, and the initial level of G_k. These elements jointly determine the trajectory of relative consumption expenditure and the broader pattern of structural transformation. Accordingly, a quantitative analysis is essential to elucidate the complex interplay between the dynamics of sectoral proximities and technology adoption efficiency, and their joint effects on the path of structural transformation.

If developing economies are in a phase of industrialization (assuming that the growth rate in manufacturing is lower than in services) and they adopt technologies from developed countries that are in a phase of deindustrialization (with a higher growth rate in manufacturing than services), then the relative productivity gap in manufacturing will widen further and the increase in the growth rate will be higher in manufacturing compare to services. This will lead to a decline in the slope of the curve for the manufacturing sector in developing countries as the relative growth rate in manufacturing becomes higher. Through technology adoption from previous developed countries, developing countries can experience a "premature" deindustrialization. This enables the proposal of the following proposition.

Proposition I. *Under Assumption I, when a developing country integrates (through technology adoption) with the technological frontier that is undergoing deindustrialization, then the consumption expenditure share of manufacturing of the country is expected to be significantly reduced.*

Proof. Let $G_s(a_m, a_s)$ denote the ratio of productivity growth rates in the manufacturing and services sectors, defined by $G_s(a_m, a_s) = (1+g_m)/(1+g_s)$. We aim to demonstrate that G_s increases when a country integrates with the technological frontier. The time subscript will be omitted for clarity, unless explicitly required.

The total variation dG_s of the function $G_s(a_m, a_s)$ following a variation in sectoral proximities to the technological frontier for productivities a_m and a_s is given by:

$$dG_s = \frac{\partial G_s}{\partial a_m} da_m + \frac{\partial G_s}{\partial a_s} da_s \tag{4.10}$$

Since the growth rate g_k of sectoral productivity A_k is decreasing with sectoral proximity a_k, $k = m,s$ then :

$$\frac{\partial G_s}{\partial a_m} < 0 \text{ and } \frac{\partial G_s}{\partial a_s} > 0 \tag{4.11}$$

As the frontier grows faster than the country in manufacturing at the integration such that $g_m < \bar{g}_m$ then a_m will decrease and da_m will be negative. If the country grows faster in services than the frontier such that $da_s > 0$ then dG_s will be positive and G_s will increase. If not, i.e. in case where $da_s < 0$, first, let us show that the growth rate of sectoral proximity to the frontier is higher in services than in manufacturing:

$$\frac{a_{st+1}}{a_{mt+1}} \Big/ \frac{a_{st}}{a_{mt}} = \frac{A_{st+1}}{\bar{A}_{st+1}} \times \frac{\bar{A}_{mt+1}}{A_{mt+1}} \times \frac{A_{mt}}{\bar{A}_{mt}} \times \frac{\bar{A}_{st}}{A_{st}} \tag{4.12}$$

By rearranging the fractions in equation (4.12) and isolating sectoral productivities at the technological frontier on one hand, and country productivities on the other hand, the following expression is derived:

$$\frac{a_{st+1}}{a_{mt+1}} \Big/ \frac{a_{st}}{a_{mt}} = \frac{1+\bar{g}_m}{1+\bar{g}_s} \Big/ \frac{1+g_m}{1+g_s} \tag{4.13}$$

Given the deindustrialization at the frontier, the numerator $(1+\bar{g}_m)/(1+\bar{g}_s)$ is greater than 1. Similarly, $(1+g_m)/(1+g_s)$ is less than 1 given that the country is undergoing industrialization. Therefore, the ratio $\frac{a_{st+1}}{a_{mt+1}} \big/ \frac{a_{st}}{a_{mt}}$ is greater than 1. Consequently, the variation rate in the sectoral proximity to the frontier will be higher in services than in manufacturing:

$$\frac{da_s}{a_s} > \frac{da_m}{a_m} \tag{4.14}$$

Let's now derive $G_s(a_m, a_s)$ with respect to its arguments. By replacing the expression of g_k , $k = m,s$, then the differential of the function $G_s(a_m, a_s)$ can be obtained as follow:

$$dG_s = \frac{(\zeta\kappa)^{1/2}}{2(1+g_s)} \left[\left(\frac{a_s}{\phi_s}\right)^{1/2} \left(a_s^{-1}+1\right) G_s(a_m,a_s) \frac{da_s}{a_s} - \left(\frac{a_m}{\phi_m}\right)^{1/2} \left(a_m^{-1}+1\right) \frac{da_m}{a_m} \right] \tag{4.15}$$

From inequality (4.14), a sign of dG can be found conditional to the values of the parameters ϕ_k , sectoral proximities a_k, and sectoral productivity growth g_k $k = m,s$:

$$dG_s > -\frac{(\zeta\kappa)^{1/2}}{2(1+g_s)^2} \left[(1+g_s) \left(\frac{a_m}{\phi_m}\right)^{1/2} \left(a_m^{-1}+1\right) - (1+g_m) \left(\frac{a_s}{\phi_s}\right)^{1/2} \left(a_s^{-1}+1\right) \right] \frac{da_s}{a_s} \tag{4.16}$$

Assumption I. *We assume that the proximity of sectoral productivities to the technological frontier a_m and a_s, as well as the growth rate of sectoral productivities g_m and g_s during the early stages of* *industrialization in developing countries, are such that:*

$$(1+g_s)(\phi_s a_m)^{1/2}(a_m^{-1}+1) > (1+g_m)(\phi_m a_s)^{1/2}(a_s^{-1}+1). \tag{4.17}$$

This hypothesis will be verified post-calibration. However, if the adjustment costs ϕ_s in the services sector significantly exceed those in the manufacturing sector ϕ_m, and during the industrialization phase $g_m < g_s$ in developing countries, it is intuitive to assume that the relationship posited in inequality (4.17) holds true.

Assuming that Assumption I holds at the beginning of integration with developed countries, then $dG_s > 0$ meaning that the relative share of services will increase over time and the slope of the curve of the manufacturing share decreasing. ■

To summarize, developing countries tend to undergo deindustrialization when they integrate with deindustrializing countries. When developing countries align their economic activities with those of deindustrializing countries, it leads to a shift away from industrialization and a decline in the manufacturing sector's relative importance. Integration with developed economies facilitates technology transfer and knowledge spillovers to developing countries. This phenomenon significantly stimulates 'catch-up' growth, especially in sectors that are farther from the technological frontier. As manufacturing tends to advance more rapidly in developed countries, a noticeable gap arises compared to the services sector in developing economies. As a result, developing countries experience higher growth rates in manufacturing relative to services. This accelerated growth in manufacturing cultivates a leapfrogging effect, thereby allowing these economies to bypass certain stages of manufacturing development and transition directly into the services sector.

4.3 Financial Development and Structural Transformation

The main force driving structural transformation in the model is sector-biased productivity growth through technology adoption. This growth hinges on a sector's initial productivity relative to the technological frontier and the level of financial development.

We now examine the impact of financial development on the pace of structural transformation. Specifically, we begin by analyzing how relative productivity growth, as defined in Equation (4.6), responds to changes in the level of financial development. To this end, we differentiate G_k with respect to κ:

$$\frac{\partial G_k}{\partial \kappa} = \frac{g_m - g_k}{2\kappa(1+g_k)^2} \tag{4.18}$$

Sectoral productivity growth differentials shape both the direction and the magnitude of the impact of financial development on structural transformation within an economy. Specifically, if the productivity growth rate in sector k exceeds that of manufacturing, an increase in the level of financial development results in a decline in the relative expenditure share of sector k, and conversely, when the inequality is reversed. Furthermore, the magnitude of this effect depends positively on the difference in sectoral productivity growth rates between sectors k and m, and inversely on the productivity growth rate in sector k.

If at a given time t_0 the growth rate in manufacturing is less than services growth then ΔG_s will be negative, and the relative sectoral productivity growth $(1+g_m)/(1+g_s)$ will be lower than in the case where there was no increase in κ. Under these conditions Ψ_{st} will also be smaller than in the case where κ had not increased, which means that the manufacturing expenditure share e_{mt} will increase with κ. If, on the other hand, at a given date t_0, the productivity growth rate in the manufacturing sector g_m is higher than that in services g_s, then $\partial G_s/\partial \kappa$ will be positive and the share of manufacturing will be lower than the case where there is not increase in κ.

Figure VII below exemplifies these two scenarios. During the industrialization phase, where the growth rate in agriculture (g_a) is greater than that in services (g_s), which in turn is greater than that in manufacturing (g_m), resources are primarily reallocated from the agricultural and service sectors a and s to the manufacturing sector m. This reallocation is further amplified by the level of financial development, favoring higher growth in the agricultural and service sectors. Conversely, during the deindustrialization phase, where the growth rates satisfy $g_a > g_m > g_s$, resource reallocation is directed more towards the service sector. This shift is again amplified by the level of financial development.

Proposition II. *Financial development drives both deindustrialization and industrialization, generating a boost in economic transformation.*

(a) Industrialization phase

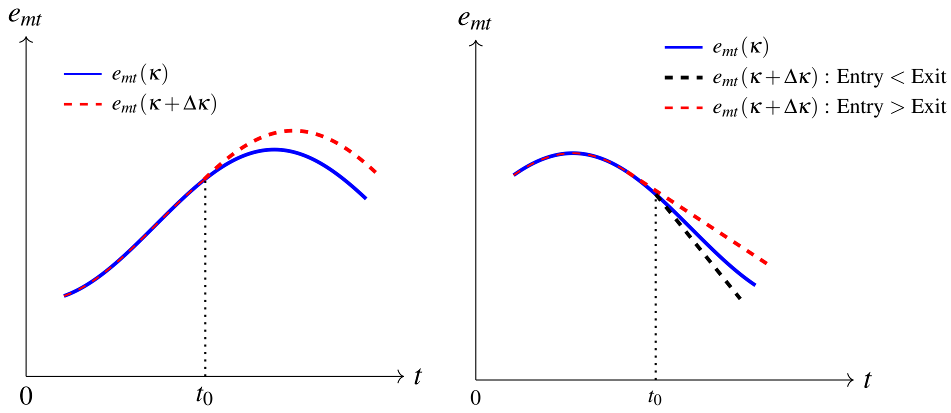
(b) Deindustrialization phase

FIGURE VII: Impact of financial development on resource reallocation across sectors

As the level of financial development increases, the sector that previously exhibited a higher growth rate also experiences a proportionally greater increase. This suggests that financial development has the potential to amplify sectoral productivity growth. Sectors that had initially demonstrated higher growth rate tend to benefit the most from this advancement. Figure VIII illustrates the impact of financial development level on the sectoral share of consumption expenditure in manufacturing. If an increase in financial development occurs before the peak of the manufacturing sector share curve, the impact is positive. This signifies that during the industrialization phase, enhanced financial development will support a higher inflow of resources into the manufacturing sector.

However, if this increase occurs after the peak, implying a deindustrialization phase, higher levels of financial development will instead spur the reallocation of resources from manufacturing to services. At the same time, it will also cause a more significant exit from the agricultural sector, thereby leading to a considerable influx into the manufacturing sector. The overall impact will thus depend on the levels of entry and exit in the manufacturing sector, which are determined by the differences in productivity growth rates across sectors.

If $\frac{g_a-g_m}{g_m-g_s} > \left(\frac{1+g_a}{1+g_s}\right)^2$, then $|\partial G_a/\partial \kappa| > \partial G_s/\partial \kappa$ and the inflow into the manufacturing sector exceeds the outflow. And, if the opposite holds, the outflow dominates, leading to a reduction in the manufacturing sector's share.



(a) An increase in κ before the peak

(b) An increase in κ after the peak

FIGURE VIII: Effect of an increase in financial development at time t_0 on manufacturing share

5 Conclusion

This paper offers a comprehensive exploration of the drivers of structural transformation, with a particular focus on the interplay of technology adoption, financial development, and sector-specific preferences. The developed three-sector endogenous growth model successfully embodies these aspects, providing a rich analytical platform for studying the nuanced dynamics of structural transformation.

The model yields insightful theoretical results. Particularly notable is the role of financial development during different phases of structural transformation. It is revealed to enhance industrialization during the relevant phase, yet contributes to deindustrialization during that respective period, highlighting the dual and context-dependent role of financial development in shaping a country's economic structure. The model also uncovers the potential for high productivity growth in sectors like agriculture in developing countries, typically further from the technological frontier. This result underscores the role of technology adoption in bridging productivity gaps across sectors and emphasizes the promise of 'catch-up growth'.

Furthermore, the findings of this study suggest that the level of industrialization in a country may be influenced when interacting with countries in a deindustrialization phase, due to variations in the proximity to the frontier of sectoral productivity. This has implications to shift resources to services bypassing the manufacturing sector.

In conclusion, this study provides valuable insights into the complex factors driving structural transformation and highlights the critical roles of technology adoption and financial development. Future research could be to employ a Ricardian trade model to explore not only the differential impacts on sectoral productivity growth rates due to integration with advanced economies, but also the direct effects on traded goods prices. Such an approach could provide a deeper understanding of the resulting employment shift towards the less-traded service sector.

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A Appendix

A.1 Mathematical Appendix

A.1.1 Housesolds' optimization

The lagragian of the household's problem is :

$$\mathscr{L}\left(C_{at}, C_{mt}, C_{st}; \lambda_t\right) = \sum_{k=a,m,s} P_{kt}C_{kt} + \lambda_t \left[1 - \delta_k^{1/\sigma}\left(\frac{C_{kt}}{C_t^{\varepsilon_k}}\right)^{\frac{\sigma-1}{\sigma}}\right] \tag{A.1}$$

where λ_t is the Lagrange multiplier. And the first order conditions are given by :

$$\frac{\partial \mathscr{L}}{\partial C_{kt}} = P_{kt} - \lambda_t \delta_k^{1/\sigma}\left(\frac{\sigma-1}{\sigma}\right)\frac{C_t^{\varepsilon_k}}{C_t^{2\varepsilon_k}}\left(\frac{C_{kt}}{C_t^{\varepsilon_k}}\right)^{-1/\sigma} = 0 \quad \forall k = a,m,s \tag{A.2}$$

Then the price of the composite good in the sector k is given by :

$$P_{kt} = \lambda_t \left(\frac{\sigma-1}{\sigma}\right)\frac{\delta_k^{1/\sigma}}{C_t^{\varepsilon_k}}\left(\frac{C_{kt}}{C_t^{\varepsilon_k}}\right)^{-\frac{1}{\sigma}} \tag{A.3}$$

And the expenditure in the consumption of the sector k final good is given by :

$$P_{kt}C_{kt} = \lambda_t \left(\frac{\sigma-1}{\sigma}\right)\delta_k^{1/\sigma}\left(\frac{C_{kt}}{C_t^{\varepsilon_k}}\right)^{1-\frac{1}{\sigma}} \quad \forall k \tag{A.4}$$

Using the equation (A.4) and the utility function equation (3.22), the total expenditure $E_t := \sum_{k=a,m,s} P_{kt}C_{kt}$ at time t is given by :

$$E_t = \lambda_t \left(\frac{\sigma-1}{\sigma}\right) \tag{A.5}$$

The expression (A.3) of the price of the final good of the sector k can then be rewriten as :

$$\frac{P_{kt}}{E_t} = \delta_k^{1/\sigma} C_{kt}^{-1/\sigma} C_t^{\varepsilon_k\left(\frac{1}{\sigma}-1\right)} \tag{A.6}$$

By rearranging, we obtain the expression for consumption in sector k as follows:

$$C_{kt} = \delta_k \left(\frac{P_{kt}}{E_t}\right)^{-\sigma} C_t^{\varepsilon_k(1-\sigma)} \quad \forall k = a,m,s \tag{A.7}$$

Next, we will derive the expression for the aggregate price. By rasing each of the equations (A.3) to the power $1-\sigma$, then one obtains :

$$P_{kt}^{1-\sigma} = \delta_k^{\frac{1-\sigma}{\sigma}} E_t^{1-\sigma} C_t^{(\sigma-1)\varepsilon_k}\left(\frac{C_{kt}}{C_t^{\varepsilon_k}}\right)^{1-\frac{1}{\sigma}} \quad \forall k \tag{A.8}$$

So

$$\delta_k P_{kt}^{1-\sigma} C_t^{(1-\sigma)\varepsilon_k} = E_t^{1-\sigma} \delta_k^{\frac{1}{\sigma}} \left(\frac{C_{kt}}{C_t^{\varepsilon_k}} \right)^{1-\frac{1}{\sigma}} \qquad \forall k = a, m, s \tag{A.9}$$

By adding the equations (A.9), we obtain :

$$\sum_k \delta_k P_{kt}^{1-\sigma} C_t^{(1-\sigma)\varepsilon_k} = E_t^{1-\sigma} \tag{A.10}$$

$$\Longrightarrow C_t^{1-\sigma} \sum_k \delta_k P_{kt}^{1-\sigma} C_t^{(1-\sigma)(\varepsilon_k - 1)} = E_t^{1-\sigma} \tag{A.11}$$

By defining the aggregate price P_t such that $P_t C_t = \sum_k P_{kt} C_{kt}$, We can deduce from the equation (A.11) the expression of P_t as follow:

$$P_t = \left[\sum_{i=a,m,s} \delta_i P_{it}^{1-\sigma} C_t^{(1-\sigma)(\varepsilon_i - 1)} \right]^{\frac{1}{1-\sigma}} \tag{A.12}$$

From the equation (A.7) we can derive the demand for the composite good k in function of the aggregate consumption and aggregate price:

$$C_{kt} = \delta_k \left(\frac{P_{kt}}{P_t} \right)^{-\sigma} C_t^{\varepsilon_k(1-\sigma)+\sigma} \qquad \forall k = a, m, s \tag{A.13}$$

The expenditure share e_{kt} of the sector k is :

$$\begin{aligned} e_{kt} &= \frac{P_{kt} C_{kt}}{P_t C_t} \\ &= \delta_k \left(\frac{P_{kt}}{P_t} \right)^{1-\sigma} C_t^{(1-\sigma)(\varepsilon_k - 1)} \qquad \forall k \end{aligned} \tag{A.14}$$

$$\begin{aligned} \Longrightarrow \frac{e_{kt}}{e_{mt}} &= \frac{\delta_k}{\delta_m} \left(\frac{P_{kt}}{P_{mt}} \right)^{1-\sigma} \times \frac{C_t^{(\varepsilon_k - 1)(1-\sigma)}}{C_t^{(\varepsilon_m - 1)(1-\sigma)}} \\ &= \frac{\delta_k}{\delta_m} \left(\frac{P_{kt}}{P_{mt}} \right)^{1-\sigma} C_t^{(\varepsilon_k - \varepsilon_m)(1-\sigma)} \end{aligned} \tag{A.15}$$

The equation (A.14) gives :

$$\begin{aligned} e_{kt} &= \delta_k \left(\frac{P_{kt}}{E_t C_t^{-1}} \right)^{1-\sigma} C_t^{(1-\sigma)(\varepsilon_k - 1)} \\ &= \delta_k \left(\frac{P_{kt}}{E_t} \right)^{1-\sigma} C_t^{(1-\sigma)\varepsilon_k} \qquad \forall k = a, m, s \end{aligned} \tag{A.16}$$

Hence,

$$C_t = \left[\left(\frac{e_{kt}}{\delta_k} \right)^{\frac{1}{1-\sigma}} \left(\frac{E_t}{P_{kt}} \right) \right]^{1/\varepsilon_k} \qquad k = a, m, s \tag{A.17}$$

Then the equation (A.15) becomes :

$$
\begin{aligned}
\frac{e_{kt}}{e_{mt}} &= \frac{\delta_k}{\delta_m}\left(\frac{P_{kt}}{P_{mt}}\right)^{1-\sigma}\left[\frac{E_t}{P_{mt}}\left(\frac{e_{mt}}{\delta_m}\right)^{\frac{1}{1-\sigma}}\right]^{\frac{(1-\sigma)(\varepsilon_k-\varepsilon_m)}{\varepsilon_m}} \\
&= \frac{\delta_k}{\delta_m}\left(\frac{P_{kt}}{P_{mt}}\right)^{1-\sigma}\left(\frac{e_{mt}}{\delta_m}\right)^{\frac{\varepsilon_k}{\varepsilon_m}-1}\left(\frac{E_t}{P_{mt}}\right)^{\frac{(1-\sigma)(\varepsilon_k-\varepsilon_m)}{\varepsilon_m}} \qquad \text{(A.18)}
\end{aligned}
$$

And the expenditure share is finally given by :

$$
e_{kt} = \delta_k\left(\frac{e_{mt}}{\delta_m}\right)^{\frac{\varepsilon_k}{\varepsilon_m}}\left(\frac{P_{kt}}{P_{mt}}\right)^{1-\sigma}\left(\frac{E_t}{P_{mt}}\right)^{(1-\sigma)\left(\frac{\varepsilon_k}{\varepsilon_m}-1\right)} \qquad \text{(A.19)}
$$

A.1.2 Aggregate behavior

$$
\begin{aligned}
VA_{kt} = &\underbrace{P_{kt}Y_{kt} - p^x_{kt}x_{kt}}_{\text{Final sector value added}} + \underbrace{(p^x_{kt}x_{kt} - P_{kt}x_{kt})}_{\text{Intermediate varieties value added}} \\
&= P_{kt}Y_{kt} - P_{kt}x_{kt} \\
&= \alpha^{\frac{2\alpha}{1-\alpha}}P_{kt}A_{kt}L_{kt} - \alpha^{\frac{2}{1-\alpha}}P_{kt}A_{kt}L_{kt} \\
&= (1-\alpha^2)\alpha^{\frac{2\alpha}{1-\alpha}}P_{kt}A_{kt}L_{kt}
\end{aligned}
$$

❖ *Calculation of GDP by income perspective*

$$
GDP_t = w_tL_t + \sum_{k=a,m,s}\Pi_{kt} \qquad \text{(A.20)}
$$

where Π_{kt} is the total profits made in sector k intermediate variety. By replacing w_t and Π_{kt} by their expression, the equation (A.20) becomes :

$$
\begin{aligned}
GDP_t &= (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}P_{kt}A_{kt}L_t + (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}\sum_{i=a,m,s}P_{it}A_{it}L_{it} \\
&= (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}P_{kt}A_{kt}L_t + (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}P_{kt}A_{kt}\sum_{i=a,m,s}L_{it} \\
&= (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}\left[1+\alpha^{\frac{1+\alpha-2\alpha}{1-\alpha}}\right]P_{kt}A_{kt}L_t \\
&= \zeta P_{kt}A_{kt}L_t \quad \forall k = a,m,s \qquad \text{(A.21)}
\end{aligned}
$$

where $\zeta := (1-\alpha^2)\alpha^{\frac{2\alpha}{1-\alpha}}$

❖ *Calculation of the GDP by value added perspective*

$$
\begin{aligned}
GDP_t &= \sum_{i=a,m,s} VA_{it} \\
&= \sum_{i=a,m,s} \zeta P_{it} A_{it} L_{it} \\
&= \zeta P_{kt} A_{kt} \sum_{i=a,m,s} L_{it} \\
&= \zeta P_{kt} A_{kt} L_t \quad \forall k = a, m, s
\end{aligned}
\tag{A.22}
$$