Financial Development and Endogenous Investment-Specific Technical Change*

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Abstract

This paper develops a quantitative framework to explain the relationship between financial development and investment-specific technical change across countries. Using a large cross-country dataset, I document that countries with more developed financial markets exhibit higher rates of investment-specific technical change, and that investment goods production is more intensive in value added from high-R&D industries than consumption goods production. To explain these findings, I develop a multi-industry endogenous growth model with credit constraints on R&D expenditures. In the model, R&D drives productivity growth, and financial development disproportionately benefits the productivity growth of high-R&D industries because they are more dependent on external financing. Taken together with the different industrial composition of final goods production, financial development endogenously generates faster productivity growth in investment goods production. The quantitative analysis shows that this endogenous channel accounts for approximately 40% of the observed cross-country relationship between financial development and investment-specific technical change.

Keywords: Financial development, Investment-specific technical change, Multi-industry endogenous growth model

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1. Introduction

Economists have long recognized that the price of investment goods relative to consumption goods declines with economic development. Figure 1 illustrates this trend in the United States between 1951 and 2020. In the literature, this decline is generally attributed to faster productivity growth in the production of investment goods relative to consumption goods, a phenomenon commonly referred to as *investment-specific technical change*. This particular form of technical change has been identified as a central driver of economic growth (Greenwood et al. 1997; Ngai and Samaniego 2009), business cycles (Greenwood et al. 2000; Justiniano et al. 2010), and other major macroeconomic trends (Karabarbounis and Neiman 2014, García-Santana et al. 2021).[1]

Despite its central role in explaining a wide range of macroeconomic phenomena, the forces underlying investment-specific technical change remain largely unexplored. This is surprising given that the data reveal markedly different growth factors of investment-specific technical change across countries. Figure 2 plots the average growth factor of the relative price of final investment goods across 115 countries between 1985 and 2007, using data from the Penn World Tables (PWT) 10.01, and indicates substantial cross-country dispersion. Specifically, some countries have experienced faster productivity growth in investment goods production relative to consumption goods production, which is reflected in average growth factors of the relative price of investment goods below one, while others experienced the opposite. Given its importance and the stark dispersion observed across countries, understanding the forces behind investment-specific technical change is essential.

In this paper, I argue that financial development is a key driver of cross-country differences in the rate of investment-specific technical change. The main contribution of the paper is to present a new mechanism through which financial development shapes the rate of investment-specific technical change. This paper differs from the existing literature in two key respects: (i) it highlights the differential effects of financial development on industry-level productivity growth through R&D, and (ii) it emphasizes the role of differences in industrial composition between final consumption and investment goods production.

I start off by presenting two novel empirical facts. First, using a large panel of countries from the PWT and multiple measures of financial development, I show that countries with more developed financial markets tend to exhibit faster declines in the relative price of investment, indicating higher rates of investment-specific technical change. Second, using

[1] For example, Karabarbounis and Neiman (2014) find that roughly half of the observed decline in the labor share can be attributed to investment-specific technical change. On the other hand, García-Santana et al. (2021) show that higher productivity growth in manufacturing than in services results in a decline in the relative price of investment, which in turn leads to faster capital accumulation and economic growth.

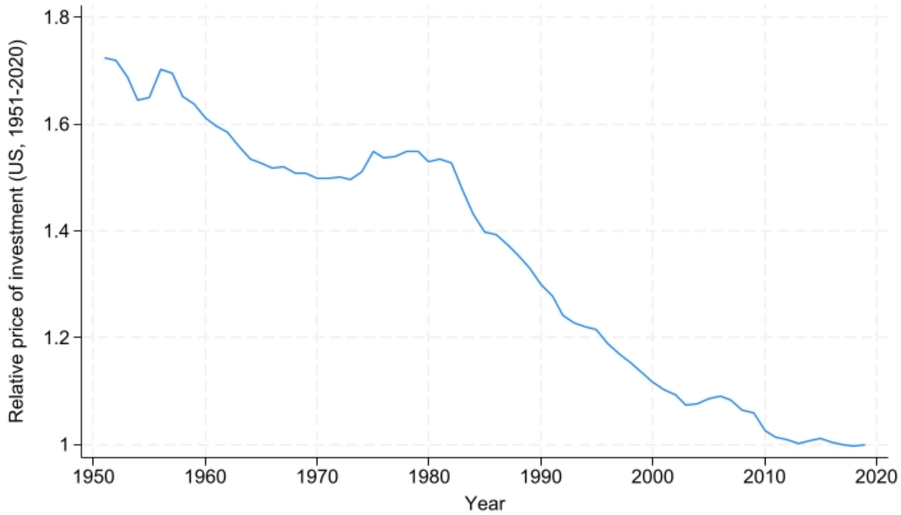


FIGURE 1. RELATIVE PRICE OF INVESTMENT IN THE UNITED STATES (1951-2020)

Notes: This figure shows the relative price of investment in the United States from 1951 to 2020. *Sources: Penn World Table 10.01*

input–output tables from the World Input–Output Database (WIOD) and the Bureau of Economic Analysis (BEA), I find that final consumption and investment goods are produced with markedly different industry compositions. In particular, I focus on the R&D intensity of each industry and show that investment goods production relies more heavily on industries with higher R&D intensities. For example, in the BEA data, the three most R&D-intensive industries account for approximately 20% of final investment goods production but only about 5% of final consumption goods production. This difference in industrial composition holds not only in the U.S. data but also across countries.

To uncover the mechanisms underlying these findings, I develop a multi-industry endogenous growth model with three key elements. The first is credit constraints on R&D expenditures, which prevent firms from choosing optimal levels of innovation investment. Financial development relaxes these constraints and enables firms to allocate more resources to R&D. The second is cross-industry heterogeneity in R&D efficiency: the same amount of R&D generates different levels of innovation across industries, so relaxing credit constraints disproportionately stimulates innovation in more R&D-efficient industries. The third is the different industrial compositions of final consumption and investment goods. Specifically, the outputs of each industry are combined to produce final consumption and investment goods through a standard CES production function, but with different share parameters and substitution elasticities.

In the model, financial development affects the rate of investment-specific technical change through two key mechanisms. First, the model indicates that financial development

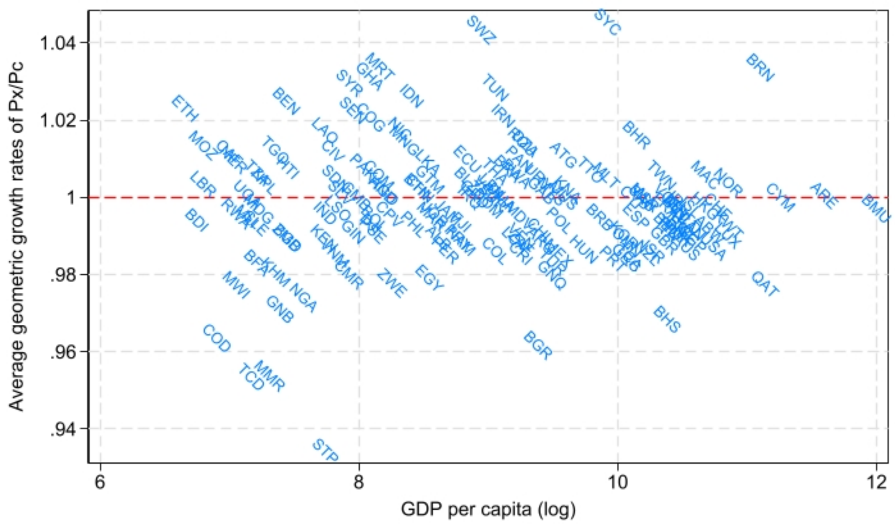


FIGURE 2. DISPERSION IN INVESTMENT-SPECIFIC TECHNICAL CHANGE ACROSS COUNTRIES

Notes: This figure shows the average geometric growth factor of the relative price of final investment goods to final consumption goods across countries. The vertical axis represents the average geometric growth factor of the relative price of investment, while the horizontal axis shows the log of real GDP per capita. The prices of final consumption and investment goods are measured using their implicit price deflators. The sample period is 1985–2007. *Sources: Penn World Table 10.01*

has larger effects on productivity growth of industries with high R&D intensity. This stems from differences in R&D efficiency across industries and the presence of credit constraints on R&D expenditures. In economies where credit constraints are binding, financial development can enhance industry-level productivity growth by enabling greater R&D investment. However, since R&D efficiency varies across industries, relaxing credit constraints is more beneficial for industries with high R&D efficiency, leading to heterogeneous effects of financial development on productivity growth across industries.

Second, because the production of investment goods relies more heavily on value added from high-R&D industries, the disproportionate productivity growth of these industries induced by financial development contributes more to productivity growth in investment goods than in consumption goods. The mechanism follows from the CES production structure: aggregate productivity growth in a final good is a weighted average of industry-level productivity growth, with weights given by value-added shares. Since high-R&D industries receive larger value-added shares in investment-goods production, productivity gains in these industries translate into faster productivity growth of investment goods production.

For example, consider two industries: a high-R&D industry (e.g., Computer and electronic products) and a low-R&D industry (e.g., Food and tobacco). Suppose there are also two countries: one with well-developed financial markets (Country A) and another with

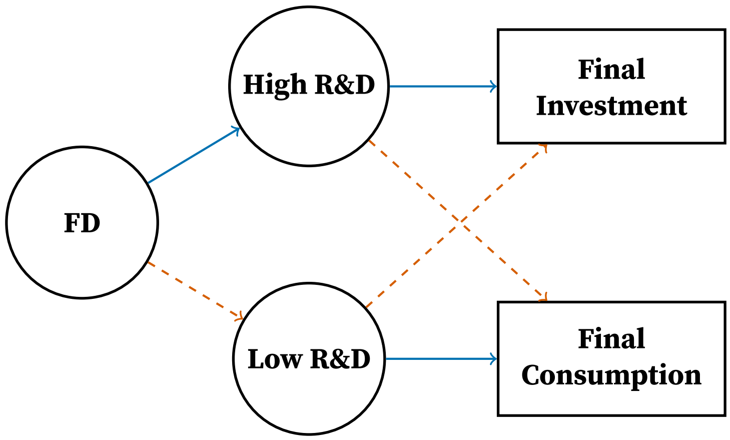


FIGURE 3. KEY MECHANISMS OF THE MODEL

Notes: This figure illustrates the key mechanisms of the model under a simplified setting with two industries. Solid blue arrows indicate strong effects or relationships, while dotted red arrows indicate weaker ones.

less-developed financial markets (Country B). In the model, the difference in productivity growth between Country A and Country B is much larger for the high-R&D industry than for the low-R&D industry. Given that investment goods production places greater weight on high-R&D industry, the higher productivity growth of the high-R&D industry in Country A results in faster growth in investment goods productivity compared to Country B. Figure 3 illustrates the key mechanisms in the simplified version of the model with two industries.

In the quantitative analysis, I examine the extent to which financial development can account for the dispersion in the rate of investment-specific technical change across countries. I begin by calibrating the model economy so as to match key aspects of the U.S. economy, which is the relatively undistorted economy with well-functioning financial markets. In the model, the observed decline in the relative price of investment can be decomposed into two components. First, there is an exogenous investment-specific technical change, which is unrelated to industry-level productivity growth. Second, endogenous investment-specific technical change arises from industry-level productivity growth, which in turn depends on the degree of financial development. Because productivity growth differs across industries, differences in industrial share parameters and elasticities of substitution generate different productivity growth rates for final consumption and investment goods.

I begin by applying the model to the U.S. economy and find that 64% of the decline in the relative price of investment between 1951 and 2017 can be attributed to the endogenous component of investment-specific technical change. I then extend the analysis to cross-country data and quantitatively examine the role of financial development in accounting for differences in the rate of investment-specific technical change across countries. The results indicate that financial development explains approximately 39% of the observed cross-country dispersion through its differential effects on industry-level productivity growth.

Given that the literature has attributed about half of the decline in the relative price of investment to endogenous investment-specific technical change, these findings suggest that financial development can account for roughly 80% of the endogenous component.

Related literature. This paper contributes to three strands of literature. First, it adds to the extensive body of work on the relationship between financial development and economic growth. While the positive effect of financial development on economic growth is well established,[2] this paper is particularly related to studies that emphasize the differential impacts of financial development on productivity growth across industries.[3] The seminal work of Rajan and Zingales (1998) document that industries more dependent on external financing tend to grow faster in countries with more developed financial markets. Ilyina and Samaniego (2011) and Ilyina and Samaniego (2012) further show that this dependence is positively associated with R&D intensity, indicating that R&D intensity is a key technological characteristic underlying the need for external finance. Similar to Aghion et al. (2005) and Ilyina and Samaniego (2012), this paper also examines the finance–R&D nexus.[4] However, its key contribution lies in presenting a previously unexplored mechanism in the finance–growth link: Financial development contributes to economic growth by increasing productivity growth in investment goods production, thereby enhancing the efficiency of capital accumulation.

Second, this paper builds on the literature on investment-specific technical change, which goes back to the seminal work of Hulten (1992), Greenwood et al. (1997), and Gordon (2007). While a large body of work has examined its macroeconomic implications, research on its underlying drivers remains limited. The paucity of studies on the sources of investment-specific technical change is surprising, given its central role in many macroeconomic phenomena. Nevertheless, some recent work has taken steps toward identifying these drivers. For example, Mutreja et al. (2018) and Lian et al. (2020) emphasize that trade in capital goods plays a key role in driving the decline in the relative price of investment and thereby promotes capital deepening.

The paper by Samaniego and Sun (2020) deserves a more detailed discussion. They examine whether cross-country differences in industrial structure in the production of investment goods can account for dispersion in rates of investment-specific technical change. Their findings suggest that countries experiencing rapid investment-specific technical change tend to have investment goods production concentrated in industries with high TFP

[2]For a comprehensive review, refer to Levine (2005).

[3]Buera et al. (2011) develop a two-sector model in which the sectors differ in fixed operating costs. Their analysis centers on aggregate TFP and the level of the relative price of manufacturing to services; by contrast, this paper emphasizes how financial development affects the rate of investment-specific technical change.

[4]There is a large literature on financial frictions and R&D. Key contributions include Brown et al. (2009), Brown et al. (2012), Howell (2017), and Ottonello and Winberry (2024). In addition, Hall and Lerner (2010) provide a comprehensive review of this topic.

growth. However, their model assumes that industry-level productivity growth rates are identical across countries, thus abstracting from the fundamental sources of cross-country differences in industry-level productivity growth.[5] This paper complements the work of Samaniego and Sun (2020) by presenting financial development as an underlying cause of cross-country differences in industry-level productivity growth.

This paper also closely relates to the literature linking R&D and investment-specific technical change. Krusell (1998) and Samaniego (2007) develop quantitative frameworks in which R&D is embodied in investment goods. By contrast, my framework does not confine R&D to investment goods; instead, productivity growth across all industries can be driven by R&D. However, credit constraints on R&D generate heterogeneous effects of financial development on industry-level productivity, which, when combined with different industrial composition, gives rise to *endogenous* investment-specific technical change.

Lastly, this paper contributes to the extensive literature on structural transformation.[6] In particular, it is closely related to García-Santana et al. (2021) and Herrendorf et al. (2021), which analyze structural change in investment.[7] These studies show that consumption and investment differ systematically in their sectoral composition, with investment relying more heavily on value added from the industrial sector. Relative to these papers, this paper makes two distinct contributions. Empirically, I document industrial composition at a more disaggregated level and highlight the role of R&D intensity. Theoretically, rather than assuming exogenous asymmetric productivity growth across sectors, I develop a quantitative framework in which *endogenous* investment-specific technical change arises from the heterogeneous effects of financial development on industry-level productivity growth.

Structure of the paper. The rest of the paper is structured as follows. In Section 2, I present two key empirical facts that motivate the paper. First, I show how financial development is related to investment-specific technical change. Second, I highlight substantial differences in the industrial composition of final consumption and investment production. In Section 3, I describe a multi-industry endogenous growth model with financial frictions and establish qualitative results regarding financial development and investment-specific technical change. In Section 4, I calibrate the model and quantify the role of financial development in investment-specific technical change. Lastly, Section 5 concludes the paper.

[5] As documented by Hsieh and Klenow (2007) and Buera et al. (2011), developing countries tend to exhibit lower productivity growth in investment goods production and manufacturing, indicating that heterogeneity in industry-level productivity growth may be a critical determinant of investment-specific technical change.

[6] Key contributions on this topic include Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008). For a comprehensive review, see Herrendorf et al. (2014).

[7] Buera et al. (2020) also show that structural transformation, particularly the reallocation within the investment sector, generates a persistent decline in the relative price of investment, thereby precluding balanced growth paths.

2. Some Facts

In this section, I present key empirical facts that motivate this paper. First, I show that the price of final investment goods relative to final consumption goods declines more rapidly in countries with more developed financial markets. This can be interpreted as faster productivity growth in the production of final investment goods compared to consumption goods. Second, I calculate the industrial composition of the two final goods production and show that final investment goods are more intensive in value added from high-R&D industries than final consumption goods are.

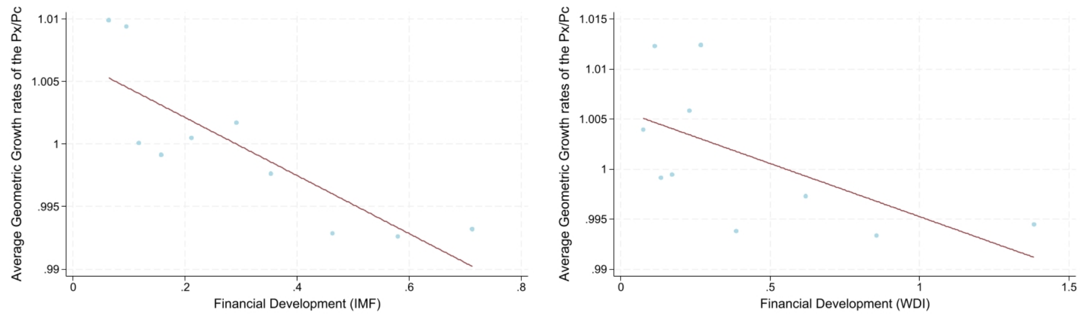
2.1. *Financial Development and Investment-Specific Technical Change*

In this subsection, I examine the relationship between the rate of investment-specific technical change and financial development. Ideally, direct measures of productivity growth for the production of consumption and investment goods would be used to examine the relationship between financial development and their relative productivity growth rates. However, such disaggregated productivity data are unavailable for most countries. As a result, I follow the standard approach in the literature (Greenwood et al. 1997; Hsieh and Klenow 2007; Buera et al. 2011; Samaniego and Sun 2020) and use the growth rate of the relative price of investment goods to consumption goods as a proxy for their relative productivity growth. Within many growth models, a higher rate of investment-specific technical change can be interpreted as a more rapid decline in the price of investment goods relative to the price of consumption goods.

The empirical facts presented in this subsection are based on several data sources. I use data on the prices of final consumption and investment goods from the PWT version 10.01. Specifically, the relative price of final investment goods is defined as the ratio of the implicit price deflator for final investment (p_{xt}) to that for final consumption (p_{ct}).[8] To measure the rate of investment-specific technical change, I compute the average geometric growth factor of the relative price of investment (p_{xt}/p_{ct}) over the sample period 1985–2007. A lower growth factor of the relative price of investment indicates a higher growth rate of the relative productivity of final investment goods production (A_{xt}/A_{ct}) over the same period.

I rely on two data sources to measure the level of financial development across countries. First, I use the Financial Development Index Database constructed by the International Monetary Fund (IMF). A key advantage of this database is that it captures the multidimensional nature of financial development, including depth, access, and efficiency in both financial institutions and markets. For this reason, I use the IMF Financial Development

[8] See Appendix A for details on variable construction.



(A) Financial Development (IMF) (B) Financial Development (WDI)

FIGURE 4. FINANCIAL DEVELOPMENT AND INVESTMENT-SPECIFIC TECHNICAL CHANGE

Notes: The figures are binscatter plots of growth rates of p_x/p_c by the level of financial development. Panel (A) uses financial development index constructed by IMF. Panel (B) uses private credit-to-GDP ratio from WDI. For variable construction and sample selection, see Appendix A. *Sources: IMF, WDI, PWT*

Index as the benchmark measure of financial development. Second, I use the private credit-to-GDP ratio from the World Development Indicators (WDI), a widely used proxy for financial development in the literature. I use the average values of these financial development measures over the sample period 1985–2007. The final dataset merges data from the PWT and the two financial development measures, covering 104 countries with IMF data and 52 countries with WDI data.

Figure 4 shows a negative relationship between the growth rate of p_x/p_c and the level of financial development. Panel A presents results using the IMF Financial Development Index, while Panel B uses the private credit-to-GDP ratio. Both panels yield the same conclusion: countries with more developed financial markets tend to exhibit significantly higher rates of investment-specific technical change, with estimated coefficients of −0.023 and −0.011, respectively, both statistically significant at the 1% level. These coefficients are also economically meaningful. For instance, based on the IMF Financial Development Index, the relative price of investment goods in a country at the 90th percentile of financial development (Spain) declined by 1.3 percentage points more per year than in a country at the 10th percentile (Madagascar).

Moreover, this negative relationship is robust to controlling for other macroeconomic variables. For example, as documented by Restuccia and Urrutia (2001) and Samaniego and Sun (2020), the cross-country dispersion in the relative price of investment goods tends to decline over time. To account for this convergence, I control for the average value of the relative price of investment goods as an additional explanatory variable. The coefficient remains negative and statistically significant. I also control for several other macroeconomic variables, and the results remain robust, as presented in Appendix C.

To summarize, the tendency for countries with more developed financial markets to exhibit higher rates of investment-specific technical change is a robust pattern in the cross-country data.

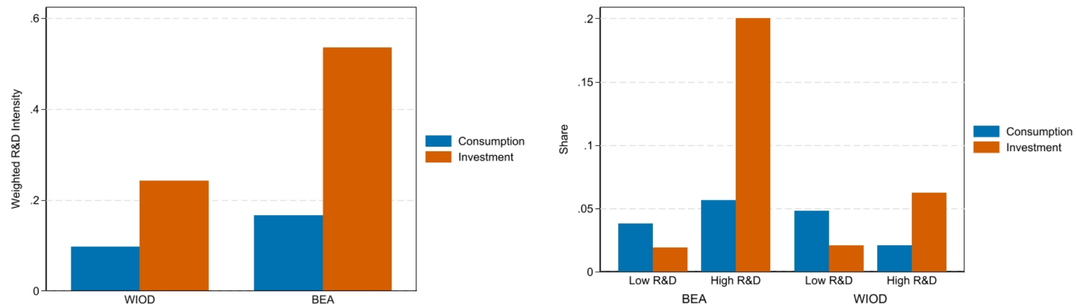
2.2. *Industrial Composition of Consumption and Investment Goods Production*

In this subsection, I document the differences in the industrial composition of final consumption and final investment production. Recent literature on structural transformation has emphasized systematic differences in the sectoral composition of consumption and investment goods production across broad sectors. For example, García-Santana et al. (2021) use the World Input–Output Database (WIOD) and find that investment goods production relies more heavily on value added from manufacturing than consumption goods production, while Herrendorf et al. (2021) use U.S. data and document that the value added share of services in final consumption and investment production has increased over time.

A key empirical contribution of this paper is to extend the existing literature by providing more disaggregated evidence on the industrial composition of final consumption and investment goods production. Specifically, I focus on industry-level R&D intensity and examine whether there is a systematic difference in R&D intensity between final investment and consumption goods production.

Accounting for the input–output structure of the economy is important, since industry-level output serves both as a direct input into the production of final consumption and investment goods and as an intermediate input into the production processes of other industries. For example, the output of the *Coke, Refined Petroleum, and Nuclear Fuel* industry is rarely used directly in final investment goods production. However, a significant fraction of this industry's output is absorbed by the *Construction* industry, which accounts for a large share of final investment production. This example underscores the importance of accounting for both direct and indirect inputs when measuring the industrial composition of final goods production. To calculate the industrial composition of the two final goods production, I construct total requirement matrices following the approach proposed by Herrendorf et al. (2013). The key idea of this approach is to trace the industrial inputs required to produce final consumption and investment. Appendix B provides details on the construction of the total requirement matrices.

Two data sources are used to calculate the industrial composition of final consumption and investment production. First, I use the WIOD 2013 release, which provides information on the input-output structure for 40 countries and 35 industries from 1995 to 2011. The main advantage of this database is that it includes both developing and developed countries, enabling a comprehensive analysis of the industrial structure of final goods production throughout the development process. I exclude three countries and the *Private Households with Employed Persons* industry, resulting in a final sample of 37 countries and 34 industries



(A) Weighted R&D intensities (B) Industry Shares: High vs. Low R&D

FIGURE 5. INDUSTRIAL COMPOSITION: FINAL CONSUMPTION VS. FINAL INVESTMENT

Notes: This figure illustrates differences in the industrial composition of final consumption and investment production by R&D intensity. The left panel displays the weighted R&D intensities of final consumption and investment, where each is calculated as the sum of industry shares in final goods production weighted by industry-level R&D intensities from Compustat. The right panel shows the combined share of the three most R&D-intensive and the three least R&D-intensive industries in final consumption and investment production. *Sources: WIOD and BEA input-output tables, Compustat*

for the period 1995–2011.[9] Second, I use the annual input-output tables from the Bureau of Economic Analysis (BEA), which cover a longer time span from 1947 to 2017. These data enable the analysis of the industrial composition of final goods production within a single country over a longer time horizon. Lastly, I use Compustat to calculate the R&D intensity of each industry. Industry-level R&D intensity is measured as the median of firm-level R&D intensities, where firm-level R&D intensity is defined as the ratio of R&D expenditures to sales. Appendix A provides a detailed discussion of the data.[10]

Figure 5 reports how the industrial composition of final consumption and investment goods production differs in terms of R&D intensity. Panel A presents the weighted R&D intensities of final consumption and investment production, using data from both the WIOD and the BEA input–output tables. The weighted R&D intensity is calculated as the sum of industry-level R&D intensities, weighted by the average industrial share in final goods production. Formally, the weighted R&D intensity for final goods $i = \{c, x\}$ is given by:

[9] I exclude the *Private Households with Employed Persons* sector because its value is zero in most countries, rendering the input-output matrix non-invertible. Additionally, I exclude China, Indonesia, and Luxembourg, as they lack data on the value-added of the *Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel* sector.

[10] Here, I focus exclusively on manufacturing industries. This is because R&D activity is highly concentrated in the manufacturing sector. For example, Helper et al. (2012) report that manufacturing accounts for approximately 68 percent of R&D expenditures in the U.S., while Autor et al. (2020) find that 71 percent of corporate patents are filed by firms in manufacturing. Accordingly, I restrict the quantitative analysis to examining how financial development differentially affects industry-level productivity growth within manufacturing. For completeness, Appendix C presents results on the industrial composition of final goods production including all industries in the sample.

$$\text{Weighted R\&D intensity}_i = \sum_j \text{share}_j^i \times \text{R\&D}_j,$$

where share_j^i is the share of industry j in the production of final good i, with c and x denoting consumption and investment, respectively. $\text{R\&D}_j$ denotes the R&D intensity of industry j, computed from Compustat. Industrial shares in final goods production are calculated by averaging across all countries and years in the WIOD, and across years in the BEA.

In Panel B, I report the shares of the three most and three least R&D-intensive industries in final goods production. To classify industries into high and low R&D industries, I first calculate firm-level R&D intensity, defined as the ratio of R&D expenditures to sales. I then compute industry-level R&D intensity as the median of firm-level R&D intensities for each decade from 1971 to 2020. I then compute the average rank of each industry's R&D intensity across the five decades from 1971 to 2020, and use these average ranks to identify the three most and three least R&D-intensive industries.[11] Despite differences in the level of industry aggregation between the two datasets, they yield broadly similar classifications of high and low R&D-intensive industries.[12]

I find that investment goods are more intensive in value added from high R&D industries than consumption goods. Panel A shows that final investment goods production is more R&D intensive than final consumption goods production. For example, in the BEA data, the weighted R&D intensities are 0.166 for consumption and 0.535 for investment, indicating that investment goods production draws disproportionately on high-R&D industries. Panel B shows that high R&D industries account for a substantial share of final investment goods production, but only a marginal share of final consumption goods production. For example, in the BEA data, the three most R&D-intensive industries comprise approximately 20% of investment goods production, compared to just 6.2% of consumption goods production. Conversely, the three least R&D-intensive industries account for around 3.8% of consumption goods production, but less than 2% of investment goods production. Results based on the WIOD data yield a similar conclusion.[13]

[11]This approach is similar to that of Herrendorf et al. (2021), who rank sectors by the share of labor compensation paid to high-skill workers each year and define skill-intensive sectors based on the average of these annual ranks.

[12]The WIOD has 14 manufacturing industries. The three most R&D-intensive industries are *Electrical and Optical Equipment, Chemicals and Chemical Products,* and *Machinery, n.e.c.,* with average ranks of 1.0, 2.0, and 3.2, respectively. In contrast, the three least R&D-intensive industries are *Wood and Products of Wood and Cork, Food, Beverages and Tobacco,* and *Coke, Refined Petroleum and Nuclear Fuel,* with average ranks of 12.4, 12.4, and 12.6, respectively. For BEA input-output table, I aggregate manufacturing industries into 12 industries. The three most R&D-intensive industries are *Machinery, Computer and electronic products, Electrical equipment appliances and components, Chemical products*, and *Motor vehicles bodies and trailers and parts, Other transportation equipment*, with average ranks of 1.2, 1.8, and 3, respectively, while the three least R&D-intensive industries are *Petroleum and coal products, Wood products,* and *Food and beverage and tobacco products,* with the average ranks of 10.8, 10.8, and 10.6, respectively.

[13]The difference in the role of high R&D industries across consumption and investment goods is more

To encapsulate, I document that investment goods production is more R&D-intensive than consumption goods production. Investment goods production not only exhibits higher weighted R&D intensity, but also involves a larger share of value added from industries with high R&D intensities.

3. The Model

In the previous section, I established that the relative price of investment goods declines more rapidly in financially developed countries and that the production of investment goods tends to be more R&D intensive than that of final consumption goods. To explain these empirical observations, I develop a multi-industry endogenous growth model incorporating three key components. The first is financial frictions in R&D investment, as in Aghion et al. (2005), which prevent firms from choosing the optimal level of R&D spending. Financial development can relax these credit constraints, thereby leading to higher R&D investment. The second is heterogeneity in R&D efficiency across industries, as in Ilyina and Samaniego (2012), resulting in differential effects of financial development on industry-level productivity growth. The third is the difference in the production functions between final consumption and investment goods, consistent with the second empirical fact presented in the previous section.

3.1. *Model Environment*

Time is discrete and indexed by t. Consider an economy composed of m countries that do not trade goods or services, but are able to benefit from each other's technological advancements through R&D activities. Following Aghion et al. (2005) and Ilyina and Samaniego (2012), countries use R&D investments to facilitate technology transfer, thereby reducing their distance from the world technology frontier. R&D activities are subject to credit constraints, meaning that R&D expenditures are partially financed through imperfect financial markets. Each country has a different level of financial development. Countries with more developed financial markets tend to face more relaxed credit constraints on R&D expenditures. Each economy consists of N industries, indexed by $j = 1, \cdots, N$, with each industry producing output that can be used for final consumption, investment, or as an input for the production of industry-specific intermediate goods.

Agents. In each period, a unit mass of agent is born endowed with one unit of labor and capital. Agents live for two periods and have a utility function, $u(c_t) + \beta u(c_{t+1})$, where $0 < \beta < 1$ is the discount factor and c_t is the aggregate consumption.

pronounced in the U.S. than in the cross-country data. I interpret this finding as evidence that the U.S. industrial structure is more concentrated in industries with high R&D intensities.

In the first period of their life, agents supply labor inelastically and rent out their capital stock k_t, earning the wage w_t and capital rental income $r_t k_t$. They choose their consumption c_{jt}, investment x_{jt}, and whether to be a worker, entrepreneur, or researcher. Researchers must also choose the level of R&D expenditures S_t, which can be used in the second period of their life. The budget constraint of the young agents is:

$$\sum_{j=1}^{N} q_{jt}(c_{jt} + x_{jt}) + S_t = w_t + r_t k_t, \tag{1}$$

where q_{jt} denotes the price of industrial good j in period t.

In the second period, agents choose their consumption and earn income according to their occupational choice, as well as from their accumulated capital. The budget constraint for the old agents is given by:

$$\sum_{j=1}^{N} q_{j,t+1} c_{j,t+1} = \Lambda_{t+1} + r_{t+1} k_{t+1}, \tag{2}$$

where $\Lambda_{t+1} = \max\left\{w_{t+1}, \Pi^E_{t+1}, \Pi^R_{t+1}\right\}$ denotes income based on occupational choice.

Capital accumulates according to the standard law of motion:

$$k_{t+1} = (1-\delta)k_t + x_t, \tag{3}$$

where $0 < \delta < 1$ is the depreciation rate, and x_t is aggregate investment.

Industrial output. Each industry j produces output using labor, capital, and a continuum of industry-specific intermediate goods, according to the production function:

$$y_{jt} = l_{jt}^{\alpha_l} k_{jt}^{\alpha_k} \int_0^1 A_{jt}(i)^{1-\alpha_z} z_{jt}(i)^{\alpha_z} di, \tag{4}$$

where y_{jt} is output, l_{jt} is labor, k_{jt} is capital, and $z_{jt}(i)$ is industry-specific intermediate good i. $A_{jt}(i)$ denotes the productivity of intermediate good i, which evolves endogenously through R&D. The average productivity in industry j in period t, denoted by A_{jt}, is given by:

$$A_{jt} = \int_0^1 A_{jt}(i) di.$$

Industry-specific intermediate goods. Industry-specific intermediate goods are produced by researchers. The productivity of intermediate good $z_{jt}(i)$ depends on the state of innovation. A successful innovation raises its productivity to the world technology frontier, while in the absence of innovation, productivity remains at its previous level:

$$A_{jt}(i) = \begin{cases} A_{jt}^* & \text{with innovation} \\ A_{j,t-1}(i) & \text{without innovation.} \end{cases}$$

A successful innovation allows the researcher to earn profits from the innovation. In particular, in the presence of innovation, one unit of $z_{jt}(i)$ can be produced using one unit of y_{jt}. In addition, for each intermediate good i, there exists a fringe of potential entrants who can imitate the latest generation of intermediate good i at a cost of $\psi > 1$ units of y_{jt}. As a result, a researcher with a successful innovation for intermediate good i is forced to set a limit price $p_{jt}(i) = \psi q_{jt}$ to prevent the fringe from earning positive profits, where $p_{jt}(i)$ is the price of intermediate good i in industry j. On the other hand, in the absence of innovation, the marginal cost of producing $z_{jt}(i)$ is ψ units of good y_{jt}, and production takes place under perfect competition, implying that $p_{jt}(i) = \psi q_{jt}$. Therefore, in both cases, the price of intermediate good i in industry j is given by:

$$p_{jt}(i) = \psi q_{jt}. \tag{5}$$

The world technology frontier. In each industry, the world technology frontier A_{jt}^* evolves over time according to:

$$A_{j,t+1}^* = (1 + g_j) A_{jt}^*,$$

where g_j is the industry-specific growth factor of the frontier. Let a_{jt} be the productivity gap in industry j at time t:

$$a_{jt} = \frac{A_{jt}}{A_{jt}^*}, \tag{6}$$

which measures the productivity level of industry j relative to the world technology frontier.

Final goods production. Final consumption and investment goods are produced using the standard CES aggregator:

$$c_t = \left[\sum_{j=1}^{N} \left(\zeta_j^c\right)^{\frac{1}{\epsilon_c}} c_{jt}^{\frac{\epsilon_c - 1}{\epsilon_c}} \right]^{\frac{\epsilon_c}{\epsilon_c - 1}}, \tag{7}$$

$$x_t = \chi_t \left[\sum_{j=1}^{N} \left(\zeta_j^x\right)^{\frac{1}{\epsilon_x}} x_{jt}^{\frac{\epsilon_x - 1}{\epsilon_x}} \right]^{\frac{\epsilon_x}{\epsilon_x - 1}}, \tag{8}$$

where $\sum_{j=1}^{N} \zeta_j^c = \sum_{j=1}^{N} \zeta_j^x = 1$. These two final goods production differ in three key dimensions. First, the production of final consumption and investment goods have different industry share parameters, ζ_j^c and ζ_j^x, respectively, reflecting differences in industrial composition consistent with the second empirical fact. Second, I allow the elasticity of substitution in consumption ϵ_c to differ from the elasticity of substitution in investment ϵ_x. Much of the literature has argued that these two elasticities of substitution are different in magnitude. In the next section, I formally estimate these two parameters using U.S. data and confirm that they are indeed different. Third, the production of investment goods features an exogenous investment-specific technical change process χ_t which is orthogonal to changes in industrial composition. This component allows me to tease out the endogenous part of productivity growth in investment goods production driven by changes in industry-level productivity growth.

Entrepreneurs. An entrepreneur in industry j produces industrial output using capital, labor, and industry-specific intermediate good i. The problem of the entrepreneur in industry j can be written as:

$$\Pi_{jt}^E = \max_{l_{jt}, k_{jt}, z_{jt}(i)} q_{jt} y_{jt} - w_t l_{jt} - r_t k_{jt} - \int_0^1 p_{jt}(i) z_{jt}(i) di,$$

where the production function and the price of intermediate good i are given by (4) and (5), respectively. First order conditions with respect to l_{jt}, k_{jt}, and $z_{jt}(i)$ are:

$$l_{jt} = \alpha_l q_{jt} \frac{y_{jt}}{w_t}, \tag{9}$$

$$k_{jt} = \alpha_k q_{jt} \frac{y_{jt}}{r_t}, \tag{10}$$

$$z_{jt}(i) = A_j(i) \left(\frac{\alpha_z}{\psi} \right)^{\frac{1}{1-\alpha_z}} l_{jt}^{\frac{\alpha_l}{1-\alpha_z}} k_{jt}^{\frac{\alpha_k}{1-\alpha_z}}. \tag{11}$$

Researchers. In each period t, researchers in industry j are matched with entrepreneurs and choose a measure $\mu_{jt} \in [0, 1]$ of intermediate goods. Among these intermediate goods, a fraction μ_{jt} randomly succeeds in innovation and their productivity is equal to the world technology frontier A_{jt}^*, while the productivity of the remaining fraction $1 - \mu_{jt}$ stays at its previous productivity level $A_{j,t-1}(i)$.

For the intermediate good i with successful innovation, the return to the researcher is

$$\pi_{jt}(i) = [p_{jt}(i) - q_{jt}] z_{jt}(i) = (\psi - 1) q_{jt} z_{jt}(i), \tag{12}$$

while the researcher earns zero profits for the intermediate good i without innovation.

Each industry exhibits a different level of R&D efficiency. Specifically, the amount of resources required to achieve the measure μ_{jt} of innovation is given by $\kappa_j n(\mu_{jt})/a_{j,t-1}$ units of labor. The function $n(\mu_{jt})$ is increasing in μ_{jt}, indicating that as a larger fraction of intermediate goods is innovated, researchers face higher research costs. I assume that $n(\mu_{jt}) = -\ln(1-\mu_{jt})$, which satisfies $\lim_{\mu \to 1} n(\mu) = \infty$, $n'(\mu) > 0$, and $n''(\mu) > 0$. Furthermore, research costs are a decreasing function of the productivity gap in the previous period, suggesting that as the productivity level approaches the world technology frontier, research costs decline. Lastly, κ_j is the key industry-specific parameter governing differences in R&D efficiency across industries; a lower value of κ_j indicates that researchers can allocate fewer resources to achieve the same level of μ_{jt}.

R&D expenditures are subject to credit constraints. In particular, R&D expenditures must be less than or equal to a certain fraction of predetermined R&D expenditures, S_t, where this fraction is determined by the level of financial development in each country. Let F denote the parameter capturing the overall level of financial development. Then, the credit constraint on R&D expenditures can be written as:

$$\frac{\kappa_j n(\mu_{jt})}{a_{j,t-1}} \leq F \cdot S_t. \tag{13}$$

The problem of the researcher in industry j can be written as:

$$\Pi^R_{jt} = \max_{\mu_{jt}} \left\{ \beta \mu_{jt} \pi_{jt}(i) - \frac{\kappa_j n(\mu_{jt})}{a_{j,t-1}} \right\}, \tag{14}$$

subject to the credit constraint (13).

Productivity dynamics. For each industry j, each intermediate good i succeeds in innovation with probability μ_{jt}. Although there is idiosyncratic uncertainty in the innovation process, there is no aggregate uncertainty because researchers choose a fixed probability μ_{jt}. Therefore, in equilibrium, productivity in the next period is a weighted sum of the world technology frontier and the previous period's productivity, where the weight is given by the probability of innovation. As a result, at the industry level, the productivity dynamics are given deterministically by:

$$A_{jt} = \mu_{jt} A^*_{jt} + (1 - \mu_{jt}) A_{j,t-1}. \tag{15}$$

Using the definition of the productivity gap in equation (6), (15) can be rewritten as

$$a_{jt} = \mu_{jt} + \frac{1 - \mu_{jt}}{1 + g_j} a_{j,t-1}.$$

3.2. *The Benchmark Economy*

I first consider the benchmark economy, where the level of financial development, F, is sufficiently high that the credit constraints in (13) do not bind for all industries. As a result, a researcher in industry j solves the unconstrained problem (14), which yields the optimal industry-level innovation effort, μ_j^*. I follow the standard assumption of Schumpeterian growth models and assume that the growth rate of the world technology frontier in each industry is determined by innovation in the benchmark economy, that is,

$$g_j = \sigma \mu_j^*, \tag{16}$$

where σ captures spillovers from innovation. Given μ_j^*, the productivity gap in industry j evolves according to

$$a_{jt} = \mu_j^* + \frac{1 - \mu_j^*}{1 + g_j} a_{j,t-1},$$

which converges to its steady-state value:

$$a_j^* = \frac{(1 + g_j)\mu_j^*}{(g_j + \mu_j^*)}, \tag{17}$$

which always lies strictly between 0 and 1. In what follows, I assume that the benchmark economy exhibits a set of unconstrained innovation efforts μ_j^* and steady-state productivity gaps a_j^*, for all j.

3.3. *Equilibrium Properties*

In this subsection, I examine the equilibrium properties of the economy described above. I begin by defining a competitive equilibrium of the model economy. Then, I derive the optimal industrial compositions of final consumption and investment expenditures. Next, I decompose the observed decline in the relative price of investment into exogenous and endogenous components of investment-specific technical change. The endogenous component is particularly important for understanding the role of financial development, as it is tied to industry-level productivity growth, which in turn depends on the degree of financial development. Lastly, I derive the dynamics of the productivity gap in constrained economies.

A competitive equilibrium. I follow the approach of Ilyina and Samaniego (2012) and consider an equilibrium with $N_t^R \geq N_t^E$, where N_t^R and N_t^E are the number of researchers and entrepreneurs, respectively. A competitive equilibrium is a set of sequences of prices $\{q_{jt}, p_{jt}(i), w_t, r_t\}$, allocations $\{l_{jt}, k_{jt}, z_{jt}, c_{jt}, x_{jt}, S_t\}$, occupational choice $\theta \in \{W, R, E\}$, innovation efforts μ_{jt} such that (a) given q_{jt}, r_t, and w_t, agents optimally determine consumption and investment subject to (1) and (2), (b) entrepreneurs optimally choose labor, capital, and intermediate goods given r_t, w_t, and p_{jt}, (c) researchers optimally choose S_t and innovation efforts μ_{jt}, (d) aggregate capital is accumulated according to (3), (e) final consumption and investment are produced according to (7) and (8), and (e) markets for all industrial goods, labor, and capital clear.

Optimal composition of final consumption and investment. The optimal industrial compositions of final consumption and investment expenditures can be derived by solving the optimization problem of agents. In particular, these compositions can be expressed as functions of relative prices, industrial share parameters, and the elasticity of substitution.

$$\frac{q_{jt}c_{jt}}{p_{ct}c_t} = \left[\sum_{j=1}^{N} \frac{\zeta_j^c}{\zeta_i^c} \left(\frac{q_{it}}{q_{jt}}\right)^{\epsilon_c - 1}\right]^{-1} \tag{18}$$

$$\frac{q_{jt}c_{jt}}{p_{xt}x_t} = \left[\sum_{j=1}^{N} \frac{\zeta_j^x}{\zeta_i^x} \left(\frac{q_{it}}{q_{jt}}\right)^{\epsilon_x - 1}\right]^{-1}, \tag{19}$$

where p_{ct} and p_{xt} denote the price indices for final consumption and investment, respectively, and are defined to satisfy:

$$p_{ct}c_t = \sum_{j=1}^{N} q_{jt}c_{jt}$$

$$p_{xt}x_t = \sum_{j=1}^{N} q_{jt}x_{jt}.$$

It can be shown that p_{ct} and p_{xt} are given by

$$p_{ct} = \left[\sum_{j=1}^{N} \zeta_j^c q_{jt}^{1-\epsilon_c}\right]^{\frac{1}{1-\epsilon_c}},$$

$$p_{xt} = \frac{1}{\chi_t}\left[\sum_{j=1}^{N} \zeta_j^x q_{jt}^{1-\epsilon_x}\right]^{\frac{1}{1-\epsilon_x}}.$$

Relative prices and productivity. As in many growth models, my model features a property whereby relative prices across industries reflect relative productivities. In addition, productivity of final consumption and investment goods can be expressed as a standard CES aggregate of industry-level productivities. Furthermore, the price of final investment relative to final consumption can be written as the inverse of their relative productivity.

Formally, the following proposition encapsulates the relationship between industry-level prices and productivities, and the relative price and productivity of final goods.

PROPOSITION 1 (Relative price and productivity). *Let p_{ct} and p_{xt} be price indices for final consumption and final investment, respectively.*

(a) The relative industrial prices are the inverse of relative industrial productivities:

$$\frac{q_{it}}{q_{jt}} = \frac{A_{jt}}{A_{it}}.$$

(b) The price of final investment goods relative to the price of final consumption goods are:

$$q_t \equiv \frac{p_{xt}}{p_{ct}} = \frac{1}{\chi_t}\frac{A_{ct}}{A_{xt}},$$

where

$$A_{ct} = \left[\sum_{j=1}^{N} \zeta_j^c A_{jt}^{\epsilon_c - 1}\right]^{\frac{1}{\epsilon_c - 1}} \quad \textit{and} \quad A_{xt} = \left[\sum_{j=1}^{N} \zeta_j^x A_{jt}^{\epsilon_x - 1}\right]^{\frac{1}{\epsilon_x - 1}}. \tag{20}$$

PROOF. See Appendix D. □

Decomposition of investment-specific technical change. The previous proposition establishes that the relative price of final investment goods can be expressed as the product of the inverse of exogenous investment-specific productivity and the relative productivity between final consumption and investment goods. The next lemma demonstrates that the observed decline in the relative price of final investment goods can be decomposed into two components: an exogenous component, which captures investment-specific technical change orthogonal to industry-level productivity growth, and an endogenous component, which reflects investment-specific technical change driven by industry-level productivity growth.

LEMMA 1 (Decomposition of ISTC). *Let $\hat{x}_t = x_{t+1}/x_t$ denote the growth factor of variable x between t and $t+1$. Then,*

$$\hat{q}_t = \underbrace{\frac{1}{\hat{\chi}_t}}_{\substack{\text{Exogenous}\\ \text{ISTC}}} \times \underbrace{\frac{\hat{A}_{ct}}{\hat{A}_{xt}}}_{\substack{\text{Endogenous}\\ \text{ISTC}}},$$

where

$$\hat{A}_{ct} = \left[\sum_{j=1}^{N} \omega_{jt}^{c} \left(\hat{A}_{jt}\right)^{\epsilon_c - 1}\right]^{\frac{1}{\epsilon_c - 1}}, \quad \textit{with} \quad \omega_{jt}^{c} = \frac{\zeta_j^c A_{jt}^{\epsilon_c - 1}}{\sum_{k=1}^{N} \zeta_k^c A_{kt}^{\epsilon_c - 1}}, \quad \textit{and}$$

$$\hat{A}_{xt} = \left[\sum_{j=1}^{N} \omega_{jt}^{x} \left(\hat{A}_{jt}\right)^{\epsilon_x - 1}\right]^{\frac{1}{\epsilon_x - 1}}, \quad \textit{with} \quad \omega_{jt}^{x} = \frac{\zeta_j^x A_{jt}^{\epsilon_x - 1}}{\sum_{k=1}^{N} \zeta_k^x A_{kt}^{\epsilon_x - 1}},$$

PROOF. The result follows immediately from Proposition 1. □

This result provides a simple approach to identifying the importance of endogenous investment-specific technical change in explaining the pace of decline in the relative price of final investment goods. In the next subsection, I show that financial development affects productivity growth unevenly across industries, with larger effects in those with high R&D efficiency. The primary objective of the quantitative analysis in the following section is to assess the extent to which the endogenous investment-specific technical change triggered by financial development can account for the observed relationship between financial development and the rate of investment-specific technical change.

Productivity dynamics. In equilibrium, it can be shown that the researcher allocates all available resources to R&D expenditures in the first period, which implies that $S_t = 1$. Let $\tilde{\mu}(n)$ be the inverse of the R&D cost function:

$$\tilde{\mu}(n) = 1 - \exp\left(-\frac{n}{\kappa_j}\right).$$

Accordingly, the credit constraint in industry j is binding if unconstrained total R&D expenditures in that industry exceed the borrowing limit, that is,

$$n(\mu_j^*) > F \cdot a_{j,t-1}.$$

If the constraint is binding then total R&D expenditures in industry j satisfies

$$\frac{-\kappa_j \ln(1 - \mu_{jt})}{a_{j,t-1}} = F.$$

As a result, the productivity gap in constrained economies evolves according to:

$$a_{jt} = \tilde{\mu}(F a_{j,t-1}, \kappa_j) + \frac{1 - \tilde{\mu}(F a_{j,t-1}, \kappa_j)}{1 + g_j} a_{j,t-1},$$

where the innovation probability is given by

$$\tilde{\mu}(Fa_{j,t-1}, \kappa_j) = 1 - \exp\left(-\frac{Fa_{j,t-1}}{\kappa_j}\right). \tag{21}$$

Then, the dynamics of industry-level productivity growth in constrained economies are given by

$$\hat{A}_{jt} \equiv \frac{A_{jt}}{A_{j,t-1}} = 1 + \tilde{\mu}(Fa_{j,t-1}, \kappa_j)\left(\frac{1+g_j}{a_{j,t-1}} - 1\right). \tag{22}$$

3.4. *Effects of Financial Development on Investment-Specific Technical Change*

In this subsection, I consider constrained economies in which the level of financial development is sufficiently low for a credit constraint to bind in at least one sector. I begin by showing that, in such environments, financial development promotes productivity growth across all industries but yields disproportionately greater benefits for those with high R&D efficiency. I then introduce two assumptions that are both empirically supported and necessary to derive the theoretical relationship between financial development and investment-specific technical change. Finally, I demonstrate that, under these assumptions, financial development can accelerate the decline in the relative price of final investment goods through the endogenous component of investment-specific technical change.

Financial development and industrial productivity. In the model, financial development affects productivity growth differently across industries, with the heterogeneity governed by the R&D efficiency parameter κ_j. The following proposition formally establishes this relationship.

PROPOSITION 2 (Financial development and industry-level productivity growth). *The effect of financial development on industry-level productivity growth can be summarized as follows.*

1. *Financial development accelerates the productivity convergence:*

$$\frac{\partial \gamma_j}{\partial F} \geq 0, \quad \textit{where } \gamma_j = \frac{a_{j,t+1}}{a_{jt}} = \frac{A_{j,t+1}/A_{jt}}{A^*_{j,t+1}/A^*_{j,t}}.$$

2. *This convergence effect is larger for industries with low κ_j:*

$$\frac{\partial \gamma_j}{\partial F \kappa_j} \leq 0.$$

PROOF. See Appendix D. □

This proposition states that while financial development promotes productivity growth across all industries, its impact critically depends on the R&D cost parameter κ_j. In particular, financial development has a disproportionately larger effect on productivity growth in industries with higher R&D efficiency. This result is consistent with the empirical evidence presented by Ilyina and Samaniego (2011), who find that R&D-intensive industries tend to experience faster growth in countries with more developed financial markets. This heterogeneous effect across industries is a key mechanism that links financial development and endogenous investment-specific technical change.

Financial development and endogenous ISTC. I present the main qualitative result on the relationship between financial development and investment-specific technical change under the following two assumptions, both of which are supported by empirical evidence. The first assumption imposes a restriction on the industrial composition of the two final goods productions.

ASSUMPTION 1. *Suppose that industries are indexed by R&D intensity, with industry 1 being the most R&D-intensive and industry N the least. Assume that*

$$\sum_{j=1}^{N} \zeta_j^c \leq \sum_{j=1}^{N} \zeta_j^x, \quad \forall\, N.$$

Assumption 1 states that investment goods production relies more heavily on high R&D-intensive industries than consumption goods production, which is consistent with the empirical evidence presented in Section 2. In the following section, I estimate the industrial share parameters and show that this assumption holds in the data. The next assumption pertains to the relative magnitudes of the elasticities of substitution across industrial goods within consumption and investment.

ASSUMPTION 2.

$$\epsilon_c \leq \epsilon_x.$$

Assumption 2 indicates that the elasticity of substitution for industrial goods in the production of final investment goods is higher than that in the production of final consumption goods. This assumption is supported by empirical evidence from García-Santana et al. (2021), which documents that the elasticity of substitution in final investment production among three broad sectoral goods—agriculture, industry, and services—is greater than the corresponding elasticity in final consumption production.[14] In the next section, I formally

[14] García-Santana et al. (2021) estimate the elasticity of substitution across sectoral value added within investment and consumption to be 0.51 and 0.01, respectively.

estimate these two elasticities and show that the elasticity of substitution within investment is greater than the elasticity of substitution within consumption.

Under these two assumptions, I derive a key result regarding the relationship between financial development and the relative price of investment goods. The following proposition formally establishes this relationship.

PROPOSITION 3 (Financial development and endogenous ISTC). *Suppose that Assumption 1 and Assumption 2 hold. Additionally, suppose that the rate of exogenous investment-specific technical change is constant across countries. Then, countries with more developed financial markets exhibit faster decrease in the relative price of investment:*

$$\frac{\partial \hat{q}_t}{\partial F} \leq 0.$$

PROOF. Given Assumptions 1 and 2, the result immediately follows from Lemma 1 and Proposition 2. □

A key implication of this proposition is that financial development leads to endogenous investment-specific technical change through its differential effects on industry-level productivity growth. This result arises from two central elements of the model. First, financial development disproportionately benefits high-R&D industries, as these industries tend to depend more heavily on external financing to engage in R&D. Second, the production of investment goods relies more intensively on high-R&D industries compared to the production of consumption goods. Consequently, financial development accelerates the decline in the relative price of investment goods, promoting more efficient and thereby faster physical capital accumulation.

4. Bringing the Model to the Data

In this section, I quantitatively examine the extent to which the model can explain the cross-country relationship between financial development and investment-specific technical change. I begin by calibrating the model to match key aspects of the US economy, which serves as a relatively undistorted and financially developed benchmark. I then vary the level of financial development to generate a set of industry-level productivity growth rates implied by the model. Given these values, I compute model-implied rates of investment-specific technical change and compare them with the data.

In the quantitative analysis, the only parameter that varies across countries is the level of financial development, which in turn determines the set of industry-level productivity growth rates. In the benchmark analysis, I assume that all countries share the same initial conditions for industry-level productivity in order to isolate the impact of financial

TABLE 1. CALIBRATED PARAMETERS

Parameter Name	Symbol	Value	Source
Labor share	α_l	0.49	Ilyina and Samaniego (2012)
Capital share	α_k	0.3	Buera et al. (2011)
Intermediate share	α_z	0.1	Ilyina and Samaniego (2012)
Discount factor	β	0.96	Annual real interest rate $r \approx 4\%$
Capital depreciation rate	δ	0.06	Greenwood et al. (1997)
Spillover parameter	σ	1.64	own calculations
Average markups	ψ	1.35	own calculations

Notes: This table summarizes calibrated parameters of the model. Sources are presented in the last column.

development on productivity growth and, consequently, on the rate of investment-specific technical change. As a robustness check, I also allow for country-specific initial conditions and find that the results remain robust under this alternative assumption.

4.1. *Calibration*

The model is calibrated to match key features of the U.S. economy, which serves as the benchmark given its relatively limited financial frictions. A first set of parameters is externally calibrated to values commonly used in the literature, while a second set is internally calibrated to U.S. data.

External calibration. The upper part of Table 1 displays externally calibrated parameters. I take the labor, capital, and intermediate shares from the literature and set them to 0.49, 0.30, and 0.10, respectively. The residual share accrues to entrepreneurs. The discount factor β is chosen to imply an annual interest rate of 4%, and the annual capital depreciation rate is set to $\delta = 0.6$.

Internal calibration. To estimate the markup parameter ψ, I follow the production function approach of De Loecker et al. (2020) and use data on publicly traded U.S. firms from Compustat over the period 1960–2015. This procedure yields an average markup of $\psi = 1.35$; see the lower panel of Table 1.

The spillover parameter σ and the industry-level R&D efficiency parameters κ_j are estimated following the approach of Ilyina and Samaniego (2012). The key idea is to jointly choose σ and κ_j so as to minimize the distance between the model-implied and observed industry-level R&D intensities in the data. More details on this approach are in Appendix E. Figure 6 shows the cross-industry relationship between the estimated R&D efficiency parameters and R&D intensity across 12 manufacturing industries. In accordance with theoretical predictions, industries with high R&D efficiency (low κ_j) tend to have higher

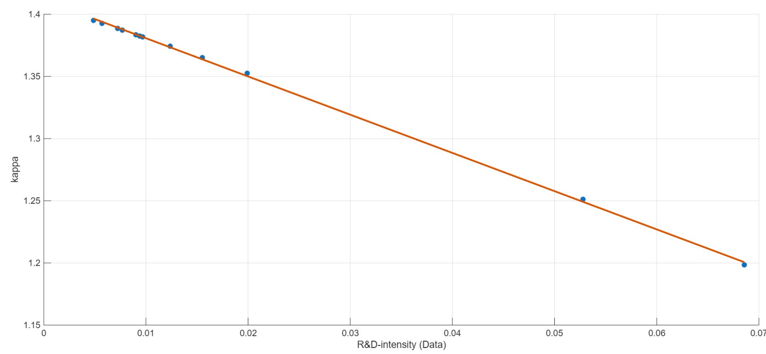


FIGURE 6. R&D INTENSITY AND R&D EFFICIENCY PARAMETERS

Notes: This figure illustrates the scatter plot of R&D intensity in the data and estimated R&D efficiency parameters κ_j.

R&D intensity. The slope coefficient of -3.075 is highly significant at the 1% level. The spillover parameter σ is estimated to be $\sigma = 1.64$.

To determine the manufacturing TFP growth rates in the benchmark economy, I start with U.S. industry-level TFP growth data from the Bureau of Labor Statistics (BLS). I then regress these TFP growth rates on industry R&D intensity. The predicted values from this regression are used as the benchmark TFP growth rates g_i.[15] TFP growth rates of nonmanufacturing sectors are also calculated from the BLS data.[16] The list of industries and corresponding TFP growth factors are presented in Table 2.

To estimate the industrial share parameters and the elasticities of substitution for final consumption and investment production, I first calculate the industrial composition of final consumption and investment using the BEA annual input-output tables from 1947 to 2017. I use disaggregated industries only for manufacturing; that is, I aggregate agriculture, mining, electricity, gas, water supply, and construction into a single sector, as these industries are not R&D-intensive. I also aggregate all service industries into one service sector. Manufacturing is disaggregated into 12 industries. Consequently, the total number of industrial share parameters to be estimated is 28: 14 for consumption and 14 for investment, see Table 2 for the list of industries for the quantitative analysis. Once the industrial composition of final consumption and investment is determined, I merge this information with the WORLDKLEMS dataset, which provides industry-level data on value added and price indices. Then, I use optimal GMM to estimate the industrial share parameters along with the two

[15]This procedure is intended to capture the link between R&D intensity and TFP growth. The regression of observed TFP growth rates on R&D intensity yields a coefficient of 0.172, which is statistically significant at the 10% level ($p = 0.078$).

[16]Since the level of aggregation in this database differs from that used in my quantitative analysis, I aggregate the TFP data from the BLS into 12 manufacturing industries using a weighted average, where the weights are given by value-added shares of each industry. For nonmanufacturing industries, I also compute the weighted average of TFP levels and their corresponding growth rates.

TABLE 2. LIST OF INDUSTRIES

Industry	NAICS	$\frac{A_{i,t+1}}{A_{it}} - 1$
Agriculture,hunting, forestry, and fishing/Mining and quarrying/Construction	11-23	0.13%
Wood products	321	0.25%
Nonmetallic mineral products	327	0.34%
Primary metals, Fabricated metal products	331, 332	0.33%
Machinery, Computer and electronic products, Electrical equipment appliances	333-335	1.42%
Motor vehicles bodies and trailers and parts, Other transportation equipment	336	0.53%
Furniture and related products, Miscellaneous manufacturing	337, 339	0.45%
Food and beverage and tobacco products	311-312	0.30%
Textile mills and textile product mills, Apparel and leather and allied products	313-316	0.31%
Paper products, Printing and related support activities	322-323	0.34%
Petroleum and coal products	324	0.27%
Chemical products	325	1.13%
Plastics and rubber products	326	0.39%
Services	42-81	0.32%

Notes: This table shows a list of industries and corresponding productivity growth factors in the benchmark economy.

elasticities of substitution. This empirical strategy is analogous to that of García-Santana et al. (2021), who apply it to cross-country data on both consumption and investment.[17] The key idea of the estimation strategy is to derive moment conditions for each industry based on equations (18) and (19), which characterize the optimal industrial composition of final consumption and investment, respectively. I relegate the details of the estimation strategy to Appendix E.

Table 3 reports the GMM estimates and GMM robust standard errors for the industrial share parameters and the elasticities of substitution within consumption and investment. Several points are noteworthy. First, the industrial compositions of final consumption and final investment differ markedly, consistent with the second empirical pattern discussed in Section 2. For example, the most R&D-intensive sector, *Machinery, Computer and Electronic Products, and Electrical Equipment, Appliances, and Components (NAICS 333–335)*, accounts for 14.57% of final investment, but only 2.63% of final consumption. In contrast, one of the least R&D-intensive sectors, *Food and Beverage and Tobacco Products (NAICS 311–312)*, accounts for 4.48% of final consumption, but less than 1% of final investment. This heterogeneity in industrial composition, combined with the differential impact of financial development on industry-level productivity growth, constitutes a key mechanism linking financial development and investment-specific technical change.

Second, the elasticity of substitution within investment is higher than that within con-

[17]The key difference is that García-Santana et al. (2021) estimate the industrial share parameters and elasticities of substitution across three broad sectors, whereas I estimate these parameters for disaggregated manufacturing industries along with the other two broad sectors.

TABLE 3. INDUSTRIAL SHARES AND ELASTICITIES OF SUBSTITUTION

PANEL A. INDUSTRIAL SHARE PARAMETERS

Industry (NAICS)	Share (con.)	Share (inv.)	Industry (NAICS)	Share (con.)	Share (inv.)
11-23	9.91% (·)	25.24% (·)	311-312	4.48% (0.0003)	0.36% (0.0001)
321	0.24% (0.0000)	1.5% (0.0002)	313-316	2.89% (0.0003)	0.71% (0.0001)
327	0.46% (0.0000)	1.84% (0.0002)	322-323	1.55% (0.0002)	1.67% (0.0002)
331, 332	2.1% (0.0003)	7.37% (0.0008)	324	1.08% (0.0003)	0.68% (0.0002)
333-335	2.63% (0.0003)	14.57% (0.0016)	325	2.84% (0.0003)	2.02% (0.0002)
336	2.48% (0.0005)	6.88% (0.0011)	326	0.83% (0.0001)	1.03% (0.0002)
337, 339	1.09% (0.0001)	1.79% (0.0002)	42-81	67.42% (0.0013)	34.3% (0.0016)

PANEL B. ELASTICITIES OF SUBSTITUTION

Parameters	Symbol	Value
Elasticity of substitution within consumption	ϵ_c	0.3263 (0.0025)
Elasticity of substitution within investment	ϵ_x	0.7172 (0.0033)

Notes: This table presents estimates of industrial share parameters and elasticities of substitution within consumption and investment. GMM robust standard errors are reported in the parentheses.

sumption, consistent with Assumption 2. This result also broadly aligns with the estimates reported in Herrendorf et al. (2021) and García-Santana et al. (2021), although my estimates are larger in magnitude. This discrepancy likely stems from differences in the level of industry aggregation. Both García-Santana et al. (2021) and Herrendorf et al. (2021) divide the economy into broad sectors, following the standard practice in the structural transformation literature.[18] Such aggregation tends to yield lower estimates of elasticities of substitution, as value added across broad sectors is less substitutable. In contrast, my estimation is based on a granular classification of the economy into 14 industries. This more disaggregated approach allows for greater substitutability in final goods production and, consequently, results in higher estimated elasticities of substitution.

4.2. *Results*

In this subsection, I quantify the impact of financial development on the rate of investment-specific technical change using the calibrated model. I begin by applying the model to the U.S. economy, where industry-level productivity growth rates are calibrated in the benchmark economy, to evaluate its performance in the absence of financial frictions. I then vary the level of financial development to generate different sets of model-implied industry-level productivity growth rates across countries. Using these model-generated growth rates and equation (20), I construct time series for the productivity of final consumption and investment goods. Finally, I compare the model-implied rates of investment-specific

[18] Herrendorf et al. (2021) divide the economy into two broad sectors: industry and services. García-Santana et al. (2021) divide the economy into three broad sectors: agriculture, manufacturing, and services.

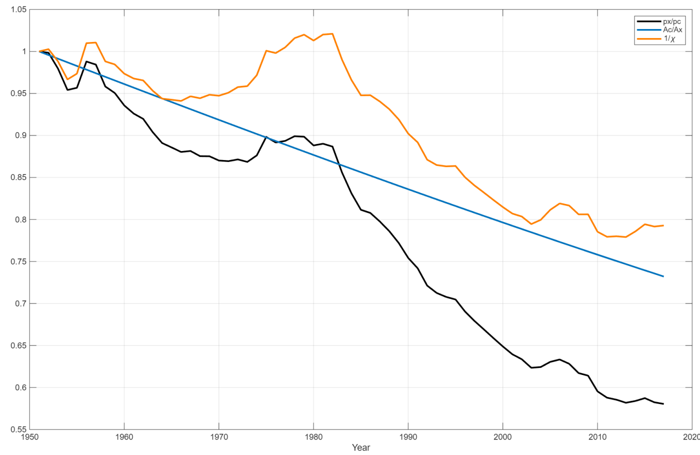


FIGURE 7. MODEL FIT: THE BENCHMARK ECONOMY (1951-2017)

Notes: This figure displays the time-series of p_x/p_c and its decomposition into exogenous and endogenous components of investment-specific technical change. *Sources: BLS, WORLDKLEMS, own calculations*

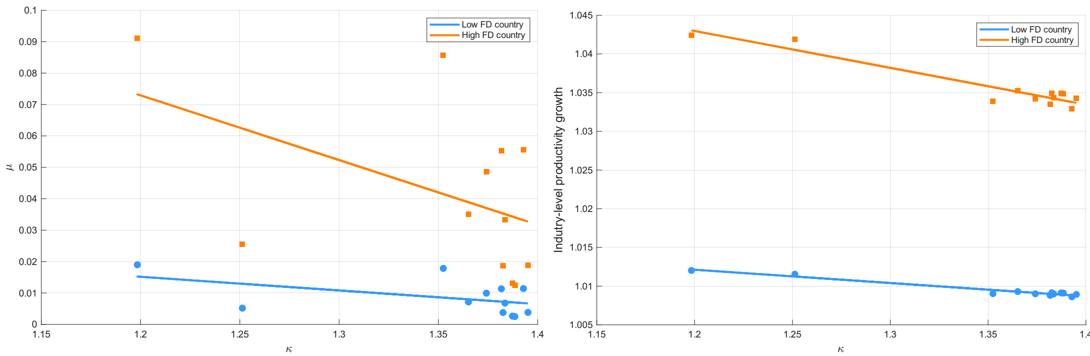
technical change with the observed values to assess the extent to which the model accounts for the cross-country relationship between financial development and investment-specific technical change.

The benchmark economy. In the previous subsection, I calibrated industry-level productivity growth rates in the benchmark economy using U.S. data. Given these calibrated values and the initial conditions for each industry, A_{i0}, I use equation (20) to construct time-series values of A_{ct}/A_{xt}, which capture the endogenous component of investment-specific technical change. Initial productivity is normalized to one in all industries.

Figure 7 plots the time series of the relative price of investment, p_x/p_c (black line), the endogenous component A_c/A_x (blue line), and the exogenous component $1/\chi$ (orange line) in the United States from 1951 to 2017. The relative price of investment exhibits a secular decline from 1 in 1951 to 0.58 in 2017, about a 42 percent decrease. In the model, the endogenous component of investment-specific technical change accounts for roughly 64 percent of this decline, falling from 1 to 0.732 over the sample period. By construction, the remainder of the decline is explained by the exogenous component of investment-specific technical change.

Despite differences in aggregation levels and the construction of industry-level productivity growth rates, this result is broadly consistent with García-Santana et al. (2021) and Herrendorf et al. (2021), both of whom find that the endogenous component of investment-specific technical change plays a significant role in explaining the decline in the relative price of investment.[19]

[19] García-Santana et al. (2021), using panel data for a large number of countries, find that the endogenous component of investment-specific technical change accounts for the overall decline in the relative price of



(A) R&D efficiency and Innovation efforts (B) R&D effieicney and productivity growth

FIGURE 8. FINANCIAL DEVELOPMENT, R&D EFFICIENCY, AND INDUSTRY-LEVEL GROWTH

Notes: The left panel of the figure illustrates the relationship between κ and innovation effort μ for countries with financial development at the 90th and 10th percentiles, respectively. The right panel shows the relationship between κ and the model-implied industry-level productivity growth rates for the same two groups. *Sources: own calculations*

Impact on industry-level productivity growth. In the model, financial development has differential impacts on industry-level productivity growth. Specifically, as financial markets develop, industries with high R&D intensity (or low κ_j) expected to experience faster productivity growth relative to less R&D-intensive industries. Put differently, countries with well-developed financial markets tend to exhibit disproportionately higher productivity growth rates in industries with high R&D intensity, whereas countries with less developed financial markets are likely to display less pronounced differences in productivity growth across industries.

In order to generate model-implied innovation efforts and industry-level productivity growth at varying levels of financial development, I proceed as follows. First, I infer initial productivity gaps (a_{jt}) using employment shares in the initial year for the United States, following the approach of Ilyina and Samaniego (2012). As a benchmark, I assume identical initial productivity gaps across countries and industries, which allows me to tease out the pure effect of financial development on industry-level productivity growth. Given the initial conditions for productivity gaps across industries and calibrated values for industry-level R&D efficiency parameters κ_j, I use (21) to generate industry-level innovation efforts across countries. Lastly, I use (22) to generate industry-level productivity growth across countries over the sample period. In the benchmark analysis, the only difference across countries is their level of financial development.

Figure 8 shows the relationship between R&D efficiency, innovation effort, and industry-level productivity growth for countries at the 90th (Singapore, orange line) and 10th (Ecuador,

investment, including half of the decline observed during the final two-thirds of the development process. On the other hand, Herrendorf et al. (2021) document that the exogenous component explains approximately 25% of the decline in the price of investment relative to services since 1980 in the United States.

blue line) percentiles of financial development. Panels A and B depict how R&D efficiency parameters relate to innovation efforts and industry-level productivity growth across industries in these two countries.

Consistent with theoretical predictions, industries with higher R&D efficiency (lower κ_j) exhibit greater innovation efforts (higher μ) and faster productivity growth. The two countries nevertheless display distinct patterns. In the high-FD country, industries with high R&D efficiency show substantially stronger innovation efforts and productivity growth, whereas in the low-FD country, these industries experience only modest increases in both dimensions. The slope coefficients are -0.0172 and -0.0476 for the low- and high-FD countries, respectively, indicating that the slope in the low-FD country is approximately 36% smaller. The slope coefficients from the regression of productivity growth on R&D efficiency are estimated at −0.0172 and −0.0476 for the low- and high-FD countries, respectively, implying that the slope in the low-FD country is about 36% smaller.

Impact on ISTC. I now evaluate the performance of the model in explaining the observed relationship between financial development and investment-specific technical change. The exercise proceeds in two steps. First, using the previously computed industry-level productivity growth rates together with the initial values of A_{jt}, I construct the relative price of investment in the final period using equation (20). Second, I compute the average geometric growth factor of this relative price over the sample period, which yields the model-implied rate of investment-specific technical change. I then assess whether the relationship between financial development and these model-implied rates corresponds to the empirical patterns. Further details are provided in Appendix E.

Figure 9 plots the effect of financial development on investment-specific technical change over the period 1987–2007. The blue solid line and the orange dotted line represent regression lines for the data and the model simulations, respectively. The horizontal axis measures financial development, and the vertical axis shows the average geometric growth factors of investment-specific technical change. As documented in Section 2, countries with more developed financial markets experience faster declines in the relative price of investment, corresponding to higher rates of investment-specific technical change. The model replicates this empirical pattern closely. The regression coefficient of the average geometric growth factors on financial development is −0.0201 in the data and −0.0078 in the simulations. The comparison of these two coefficients indicates that the model explains about 39% of the cross-country relationship between financial development and investment-specific technical change.[20]

[20] In Appendix C, I show that the results are robust to using country–industry-specific initial values for a_j. In particular, the corresponding regression coefficient under this alternative specification is −0.0084, suggesting that accounting for heterogeneous initial conditions slightly improves the fit of the model.

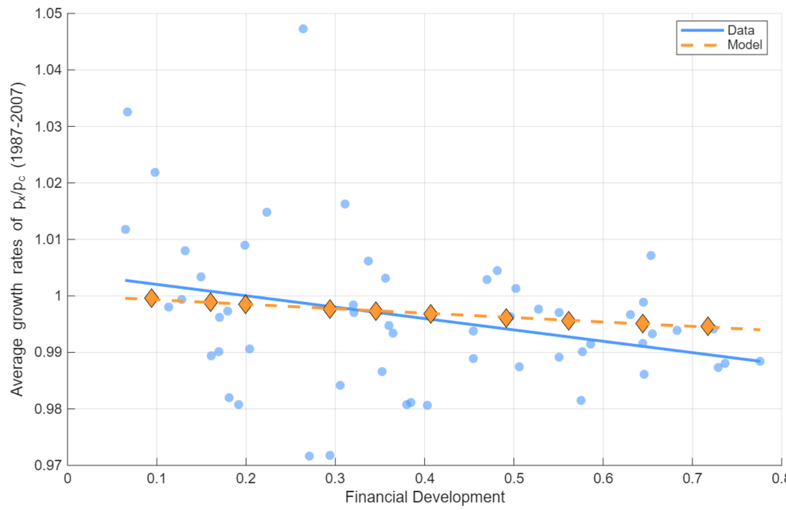


FIGURE 9. MODEL FIT: FINANCIAL DEVELOPMENT AND ISTC

Notes: This figure plots the average geometric growth rates of the relative price of investment (p_x/p_c) in the data (blue dots) along with its fitted line (blue solid line) and the model-implied fitted line (orange dotted line). The final sample includes 55 countries. For details on the sample selection and the construction of the final dataset, see Appendix A. *Sources: BLS, WORLDKLEMS, own calculations*

Discussion. I now discuss the results of the paper, especially in relation to the existing literature. Using a large panel of countries, García-Santana et al. (2021) show that the endogenous component of investment-specific technical change, driven by higher productivity growth in the manufacturing sector relative to the service sector, is a key factor behind the observed decline in the relative price of investment. Relative to their framework, which assumes exogenous sectoral productivity growth, my model endogenizes industry-level productivity growth rates as a function of financial development. Quantitatively, their findings suggest that about half of the decline in the relative price of investment can be attributed to the endogenous component of investment-specific technical change. Despite differences in country coverage and sample periods, my results broadly suggest that financial development can account for approximately 79% of the observed effect of endogenous investment-specific technical change documented in García-Santana et al. (2021).

In my framework, the impact of financial development on the relative price of investment operates only through the endogenous component of ISTC, that is, through its effect on innovation and industrial productivity growth. Exogenous investment-specific technical change, captured by χ_t, is assumed to be unrelated to financial development. However, in practice, financial development could also shape the evolution of exogenous investment-specific technical change. For example, financial frictions may prevent firms from importing capital goods and thereby fully benefit from globally cheaper capital goods.[21]

[21] Kohn et al. (2023) show that financially underdeveloped economies benefit less from tariff reductions. Kohn

Accordingly, my estimates should be interpreted as a lower bound on the overall effect of financial development on the relative price of investment.

5. Conclusions

The literature has highlighted the central role of investment-specific technical change in shaping many macroeconomic phenomena, yet its underlying drivers and cross-country patterns remain largely unexplored. This paper combines empirical evidence with a quantitative framework to highlight the role of financial development in shaping the rate of investment-specific technical change.

In this paper, I develop a quantitative framework that links financial development to investment-specific technical change. In the model, financial development relaxes credit constraints on R&D, thereby generating disproportionately faster productivity growth in R&D-intensive industries. Given the relatively R&D-intensive nature of final investment production compared with final consumption production, financial development leads to a faster decline in the relative price of investment. These heterogeneous effects of financial development on industry-level productivity growth rates constitute the endogenous component of investment-specific technical change.

In the quantitative analysis, I calibrate the model to the U.S. economy and vary only the level of financial development to generate model-implied values of investment-specific technical change. Comparing these model-implied values with the observed rate, I find that the novel mechanism of this paper accounts for approximately 39% of the cross-country relationship between financial development and investment-specific technical change. This finding suggests that the model explains roughly 80% of the decline in the relative price of investment attributable to the endogenous component of investment-specific technical change.

My theoretical framework and quantitative analysis have revolved around cross-industry heterogeneity in R&D efficiency. Combined with differences in the industrial composition of final goods production, this heterogeneity constitutes a key mechanism linking financial development to investment-specific technical change, and it proves to be quantitatively important. This mechanism highlights how financial development operates as a previously underexplored determinant of cross-country differences in investment-specific technical change.

et al. (2022) provides an extensive review of how financial development is associated with international trade. The role of capital goods trade in shaping the relative price of investment has also been studied extensively; see Eaton and Kortum (2001), Mutreja et al. (2018), and Lian et al. (2020).

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Appendix A. Data Description

In Appendix A, I describe the datasets used in the analysis and the procedures employed to construct the variables.

A.1. *Penn World Tables*

I use the Penn World Table (PWT) 10.01 to compute growth factors for the relative price of investment. Using the National Accounts series, I construct implicit price deflators for consumption and investment by dividing nominal consumption and investment by their counterparts at constant 2017 national prices. The relative price of investment is then measured as the ratio of the investment deflator to the consumption deflator, and its growth factors are calculated from this series.

Once the series for the relative price of investment is constructed, I restrict the data to a strongly balanced panel covering the period 1987–2007. I then compute the average geometric growth factor across countries to assess whether the relative price of investment has tended to rise or fall over time. To ensure comparability, I exclude hyperinflationary economies, very small countries, and countries that experienced changes of more than 50% in the relative price of investment on more than three occasions during the sample period. The resulting database is merged with two financial development datasets, which are discussed below.

A.2. *Measures for Financial Development*

I use two measures for financial development. For the benchmark measure of financial development, I use the Financial Development Index Database constructed by the IMF. The key advantage of this dataset is its consideration of the multidimensional aspects of financial development. Specifically, it summarizes the depth, access, and efficiency of financial institutions and markets. As an alternative measure of financial development, I use the WDI to obtain data on financial development. Financial development is measured using the domestic credit to private sector as a percentage of GDP. This measure includes financial resources provided to the private sector by financial corporations, such as loans, purchases of non-equity securities, trade credits, and other accounts receivable that establish a claim for repayment.

A.3. *The World Input-Output Database (WIOD)*

I use the 2013 release of the World Input-Output Database (WIOD), which contains information on input-output tables for 40 countries and 35 industries over the sample period

1995–2011. I exclude the *Private Households with Employed Persons* sector because its value is zero in most countries, rendering the input-output matrix non-invertible. Additionally, I exclude China, Indonesia, and Luxembourg, as they lack data on the value-added of the *Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel* sector.

A.4. *BEA Value Added by Industry*

The BEA provides value-added by industry data, along with corresponding quantity and price indices, for the period 1947–2017.[22] In this database, 19 manufacturing industries are reported alongside other sectors of the economy. For the analysis, I aggregate the 19 manufacturing industries into 12 broader categories. In addition, I combine *Agriculture, Forestry, Fishing, and Hunting*; *Mining*; *Utilities*; and *Construction* into a single large sector. Similarly, I group *Wholesale Trade*; *Retail Trade*; *Transportation and Warehousing*; *Information*; *Finance, Insurance, Real Estate, Rental, and Leasing*; *Professional and Business Services*; *Educational Services, Health Care, and Social Assistance*; and *Arts, Entertainment, Recreation, Accommodation, and Food Services* into another large sector.

A.5. *Use-Make Tables from the Bureau of Economic Analysis (BEA)*

I use the "Use–Make Tables" from the BEA to construct the industrial composition of value added in final consumption and investment. Given changes in the level of aggregation over time, I adopt the same level of aggregation as in the BEA Value Added by Industry dataset, namely 12 manufacturing industries and two broad sectors.[23]

A.6. *Compustat*

I use Compustat to calculate industry-level R&D intensity and to classify industries as high- or low-R&D. Following the standard approach in the literature, I restrict the sample to firms incorporated in the United States, exclude observations with missing or negative values for sales or R&D, and drop firms whose R&D-to-sales ratio exceeds one. The sample period spans 1971–2020, and industry-level R&D intensity is defined as the median of firm-level R&D intensity over this period.

Appendix B. Constructing Total Requirement Matrices

In Appendix B, I explain the procedure to construct the total requirement matrix (henceforth TR matrix) to calculate industrial composition of two final goods production. This approach

[22] https://www.bea.gov/sites/default/files/2018-04/GDPbyInd_GO_1947-2017.xlsx

[23] The database reports 46 sectors for 1947–1962, 65 sectors for 1963–1996, and 71 sectors for 1997–2017.

is largely based on the methodology developed by Herrendorf et al. (2013). I follow the approach of Herrendorf et al. (2013) and García-Santana et al. (2021) and assume that each industry produces one commodity and each commodity is produced by one industry.[24]

Suppose that there are n industries and let $\mathbf{A} = [a_{ij}]_{n\times n}$ be the $(n \times n)$ transaction matrix. The (i, j)-th element of the transaction matrix a_{ij} is the dollar amount of commodity i that industry j uses per dollar of output it produces. Let $\mathbf{q}$ be the $(n \times 1)$ output vector of domestically produced commodities. The i-th element of $\mathbf{q}$ represents the total dollar value of commodity i delivered both to other domestic industries as intermediate inputs and to final uses. Let $\mathbf{g}$ be the $(n \times 1)$ gross output vector, whose j-th element is the dollar amount of output of industry j. Lastly, let $\mathbf{e}$ denote the $(n \times 1)$ final expenditure vector, whose i-th element is the dollar value of final uses of commodity i, including consumption, domestic investment, and net exports.

The following two identities characterize the relationship between these three matrices and the TR matrix:

$$\mathbf{q} = \mathbf{A}\mathbf{g} + \mathbf{e}, \tag{B1}$$

$$\mathbf{q} = \mathbf{g}. \tag{B2}$$

The first identity states that the value of domestically produced commodities equals the sum of intermediate uses and final uses. The second identity indicates that the total value of a commodity equals the total output of its industry, which follows from the assumption that each industry produces exactly one commodity. Solving these two identities for $\mathbf{g}$ gives:

$$\mathbf{g} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{e}, \tag{B3}$$

where $\mathbf{I}$ is the $(n \times n)$ identity matrix. The matrix $\mathbf{R} = (I - A)^{-1}$ is the TR matrix, whose (i, j)-th element represents the dollar value of industry j's production that is required, both directly and indirectly, to deliver one dollar of domestically produced commodity i to final uses.

Let $\mathbf{v}$ be the $(1 \times n)$ vector whose j-th element is the ratio of value added to gross output in industry j. Also, let $\langle\mathbf{v}\rangle$ be the diagonal matrix with the entries of vector $\mathbf{v}$ on its diagonal. Combining the TR matrix with the final expenditure vectors gives

$$\mathbf{VA}_c = \langle\mathbf{v}\rangle\mathbf{R}\mathbf{e}_c, \tag{B4}$$

$$\mathbf{VA}_x = \langle\mathbf{v}\rangle\mathbf{R}\mathbf{e}_x, \tag{B5}$$

where $\mathbf{VA}_c$ and $\mathbf{VA}_x$ denote the industrial compositions of value-added use for consumption and investment, respectively. Lastly, dividing each element by the sum of all elements in

[24] This structure is analogous to the IO Tables provided by the BEA before 1972.

each vector gives industrial shares for final consumption and investment:

$$\frac{\text{VA}_i^c}{\text{VA}^c} = \frac{\mathbf{VA}_c(i)}{\sum_{i=1}^{N} \mathbf{VA}_c(i)}, \tag{B6}$$

$$\frac{\text{VA}_i^x}{\text{VA}^x} = \frac{\mathbf{VA}_x(i)}{\sum_{i=1}^{N} \mathbf{VA}_x(i)}. \tag{B7}$$

Appendix C. Omitted Tables and Figures

In Appendix C, I provide omitted tables and figures.

C.1. *Financial Development and investment-specific technical change*

In this subsection, I present results on the relationship between financial development and the rate of investment-specific technical change across countries, controlling for additional variables. Tables Table C1 and Table C2 report estimation results using the IMF Financial Development Database and the private credit-to-GDP ratio from the WDI, respectively, as measures of financial development. The final sample comprises 104 countries for the IMF database and 52 countries for the WDI database.

Table C1. Financial Development and Investment-Specific Technical Change (IMF)

	Average geometric growth rates of p_x/p_c			
	(1)	(2)	(3)	(4)
Financial Development (IMF)	-0.023***	-0.021***	-0.018**	-0.018**
	(0.005)	(0.004)	(0.007)	(0.007)
$\log(p_x/p_c)$		-0.021**	-0.021**	-0.021**
		(0.009)	(0.009)	(0.009)
log(GDP per capita)			-0.001	-0.001
			(0.001)	(0.001)
Trade share				0.003
				(0.002)
Obs.	104			
R-squared	0.128	0.303	0.305	0.312

Notes: The dependent variable is the average geometric growth rate of the price of investment goods relative to the price of consumption goods over 1985–2007. *Sources*: PWT 10.01 and IMF. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

TABLE C2. FINANCIAL DEVELOPMENT AND INVESTMENT-SPECIFIC TECHNICAL CHANGE (WDI)

	Average geometric growth rates of p_x/p_c			
	(1)	(2)	(3)	(4)
Financial Development (WDI)	-0.011***	-0.011***	-0.009*	-0.009*
	(0.003)	(0.003)	(0.005)	(0.005)
$\log(p_x/p_c)$		-0.011	-0.011	-0.011
		(0.010)	(0.011)	(0.011)
$\log$(GDP per capita)			-0.000	-0.001
			(0.002)	(0.002)
Trade share				0.001
				(0.002)
Obs.	52			
R-squared	0.100	0.160	0.161	0.163

Notes: The dependent variable is the average geometric growth rate of the price of investment goods relative to the price of consumption goods over 1985–2007. *Sources*: PWT 10.01 and WDI. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Column (1) of each table reports the bivariate regression of the average geometric growth rate of the relative price of investment on financial development. Column (2) additionally controls for the average relative price of investment to capture the convergence effect highlighted by Restuccia and Urrutia (2001) and Samaniego and Sun (2020). Column (3) adds the average GDP per capita over the sample period to control for the overall level of development across countries. Finally, column (4) includes trade share to control for the effect of trade openness on the rate of investment-specific technical change, as emphasized by Mutreja et al. (2018) and Lian et al. (2020). The results indicate that the negative relationship between financial development and the rate at which the relative price of investment declines over time is robust to the inclusion of additional controls.

C.2. *Industrial composition of final goods production*

In this subsection, I present the industrial composition of final consumption and investment goods production using the WIOD and BEA input–output tables. Tables Table C3 and Table C4 report the industrial composition of final consumption and investment goods production, respectively, based on the WIOD. Tables Table C5 and Table C6 present the corresponding compositions using the BEA input–output tables.

TABLE C3. Final Consumption Production Share

Industry	Share
Real Estate Activities	12.094%
Public Admin and Defence; Compulsory Social Security	10.474%
Health and Social Work	7.501%
Education	7.230%
Agriculture, Hunting, Forestry and Fishing	6.886%
Financial Intermediation	5.916%
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	5.306%
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	5.225%
Other Community, Social and Personal Services	4.507%
Renting of M&Eq and Other Business Activities	4.427%
Food, Beverages and Tobacco	3.897%
Hotels and Restaurants	3.518%
Electricity, Gas and Water Supply	3.273%
Inland Transport	2.980%
Post and Telecommunications	2.480%
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	1.756%
Construction	1.554%
Pulp, Paper, Paper , Printing and Publishing	1.371%
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	1.282%
Chemicals and Chemical Products	1.045%
Textiles and Textile Products	1.009%
Mining and Quarrying	0.848%
Basic Metals and Fabricated Metal	0.812%
Transport Equipment	0.643%
Coke, Refined Petroleum and Nuclear Fuel	0.624%
Machinery, Nec	0.539%
Manufacturing, Nec; Recycling	0.531%
Electrical and Optical Equipment	0.517%
Other Non-Metallic Mineral	0.438%
Rubber and Plastics	0.373%
Air Transport	0.344%
Wood and Products of Wood and Cork	0.287%
Leather, Leather and Footwear	0.191%
Water Transport	0.123%

Notes: This tables present industrial composition of final consumption goods production calculated using the WIOD. *Source*: WIOD

TABLE C4. Final Investment Production Share

Industry	Share
Construction	32.669%
Renting of M&Eq and Other Business Activities	8.572%
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	7.396%
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	5.976%
Real Estate Activities	5.200%
Basic Metals and Fabricated Metal	3.885%
Financial Intermediation	3.657%
Other Non-Metallic Mineral	3.026%
Inland Transport	2.692%
Machinery, Nec	2.604%
Electrical and Optical Equipment	2.535%
Agriculture, Hunting, Forestry and Fishing	2.440%
Mining and Quarrying	1.995%
Electricity, Gas and Water Supply	1.965%
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	1.706%
Transport Equipment	1.593%
Post and Telecommunications	1.361%
Pulp, Paper, Paper , Printing and Publishing	1.276%
Other Community, Social and Personal Services	1.242%
Manufacturing, Nec; Recycling	1.156%
Wood and Products of Wood and Cork	1.128%
Chemicals and Chemical Products	1.094%
Rubber and Plastics	0.831%
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	0.741%
Public Admin and Defence; Compulsory Social Security	0.671%
Textiles and Textile Products	0.517%
Hotels and Restaurants	0.484%
Food, Beverages and Tobacco	0.479%
Coke, Refined Petroleum and Nuclear Fuel	0.464%
Education	0.199%
Air Transport	0.164%
Health and Social Work	0.147%
Water Transport	0.114%
Leather, Leather and Footwear	0.024%

Notes: This tables present industrial composition of final investment goods production calculated using the WIOD. *Source*: WIOD

TABLE C5. Final Consumption Production Share

Industry	NAICS	Share
Agriculture,hunting, forestry, and fishing/Mining and quarrying/Construction	11-23	7.347%
Wood products	321	0.163%
Nonmetallic mineral products	327	1.601%
Primary metals, Fabricated metal products	331, 332	0.346%
Machinery, Computer and electronic products, Electrical equipment appliances	333-335	1.691%
Motor vehicles bodies and trailers and parts, Other transportation equipment	336	1.795%
Furniture and related products, Miscellaneous manufacturing	337, 339	1.870%
Food and beverage and tobacco products	311-312	0.750%
Textile mills and textile product mills, Apparel and leather and allied products	313-316	3.017%
Paper products, Printing and related support activities	322-323	1.471%
Petroleum and coal products	324	1.190%
Chemical products	325	0.625%
Plastics and rubber products	326	2.014%
Services	42-81	77.129%

Notes: This tables present industrial composition of final consumption goods production calculated using the U.S data. *Source*: BEA, BLS

TABLE C6. Final Investment Production Share

Industry	NAICS	Share
Agriculture,hunting, forestry, and fishing/Mining and quarrying/Construction	11-23	22.679%
Wood products	321	1.207%
Nonmetallic mineral products	327	1.601%
Primary metals, Fabricated metal products	331, 332	6.730%
Machinery, Computer and electronic products, Electrical equipment appliances	333-335	12.279%
Motor vehicles bodies and trailers and parts, Other transportation equipment	336	6.063%
Furniture and related products, Miscellaneous manufacturing	337, 339	1.520%
Food and beverage and tobacco products	311-312	0.270%
Textile mills and textile product mills, Apparel and leather and allied products	313-316	0.457%
Paper products, Printing and related support activities	322-323	1.408%
Petroleum and coal products	324	0.455%
Chemical products	325	1.699%
Plastics and rubber products	326	0.894%
Services	42-81	42.739%

Notes: This tables present industrial composition of final investment goods production calculated using the U.S. data. *Source*: BEA, BLS

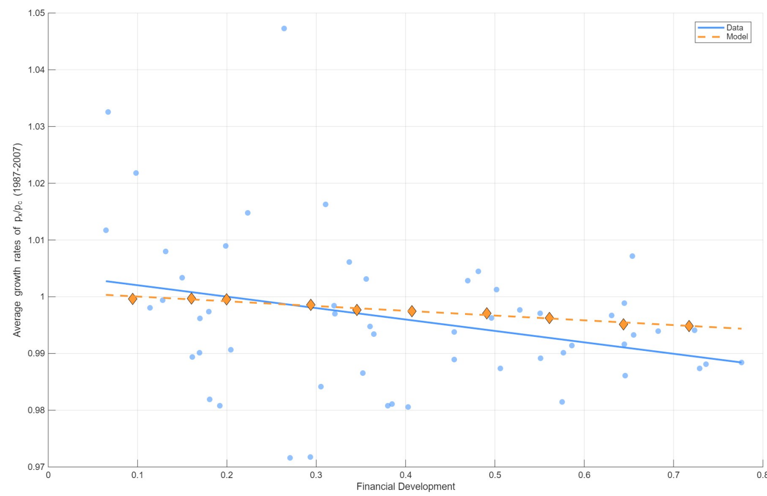

FIGURE C1. MODEL FIT: FINANCIAL DEVELOPMENT AND ISTC (DIFFERENT INITIAL CONDITIONS)

Notes: This figure plots the average geometric growth rates of the relative price of investment (p_x/p_c) in the data (blue dots) along with its fitted line (blue solid line) and the model-implied fitted line (orange dotted line). The final sample includes 55 countries. The slope coefficient in this graph is -0.0084. *Sources: BLS, WORLDKLEMS, own calculations*

C.3. *Additonal Quantitative Results*

In this subsection, I present the main quantitative results using country-specific initial conditions. The initial conditions refer to the industrial composition in the initial year, 1987. In that year, each country may exhibit a different industrial composition, which corresponds to a_{jt} in the model. Following Ilyina and Samaniego (2012), I use industrial employment shares in 1987 from the INDSTAT database as a proxy for a_{jt}. In particular, I regress the industrial employment share in 1987 on industry and country fixed effects and use residuals as a proxy for a_{jk}. I impose the restriction that the values of a_{jk} cannot exceed 1. The results are presented in Figure C1. Allowing for different states of technology in the initial period slightly improves the fit of the model. The estimated slope coefficient is -0.0084, which imlies that the model accounts for approximately 41.8% of the observed relationship between financial development and investment-specific technical change.

APPENDIX D. OMITTED DERIVATIONS AND PROOFS

Appendix D provides the omitted model derivations and the proofs of the propositions.

D.1. *Omitted Proofs*

Proof of Proposition 1. The proof begins by solving the opmization problem of the agent. We assume that the utility function is linaer. The Lagrangian can be wrttien as

$$\mathcal{L} = c_t + \beta c_{t+1} + \lambda_{1t}\left[w_t + r_t k_t - \sum_{j=1}^{N} q_{jt}(c_{jt} + x_{jt})\right] \tag{D1}$$

$$+ \lambda_{2t}\left[r_{t+1}((1-\delta)k_t + x_t) + \Lambda_{t+1} - \sum_{j=1}^{N} q_{j,t+1}c_{j,t+1}\right]. \tag{D2}$$

First order conditions with respect to c_{jt} and x_{jt} are

$$\left(\zeta_j^c\right)^{\frac{1}{\epsilon_c}} c_{jt}^{-\frac{1}{\epsilon_c}} c_t^{\frac{1}{\epsilon_c}} = \lambda_{1t} q_{jt} \tag{D3}$$

$$\lambda_{1t} q_{jt} = \lambda_{2t} r_{t+1} \left(\zeta_j^x\right)^{\frac{1}{\epsilon_x}} x_{jt}^{-\frac{1}{\epsilon_x}} x_t^{\frac{1}{\epsilon_x}} \chi_t^{\frac{\epsilon_x - 1}{\epsilon_x}}. \tag{D4}$$

Let p_{ct} and p_{xt} denote the ideal price indices for aggregate consumption and investment, respectively. Then, they satisfy

$$\sum_{j=1}^{N} q_{jt} c_{jt} = p_{ct} c_t \tag{D5}$$

$$\sum_{j=1}^{N} q_{jt} x_{jt} = p_{xt} x_t. \tag{D6}$$

Raising power to the $1-\epsilon_c$ and summing over j (D3) give

$$1 = \lambda_{1t}\left[\sum_{j=1}^{N} \zeta_j^c q_{jt}^{1-\epsilon_c}\right]^{\frac{1}{1-\epsilon_c}}. \tag{D7}$$

In addition, (D3) implies that

$$\lambda_{1t} \sum_{j=1}^{N} q_{jt} c_{jt} = c_t^{\frac{1}{\epsilon_c}} \sum_{j=1}^{N} \left(\zeta_j^c\right)^{\frac{1}{\epsilon_c}} c_{jt}^{\frac{\epsilon_c - 1}{\epsilon_c}} = c_t. \tag{D8}$$

Therefore, we have

$$\sum_{j=1}^{N} q_{jt} c_{jt} = \lambda_{1t}^{-1} c_t = p_{ct} c_t, \tag{D9}$$

where

$$p_{ct} = \lambda_{1t}^{-1} = \left[\sum_{j=1}^{N} \zeta_j^c q_{jt}^{1-\epsilon_c} \right]^{\frac{1}{1-\epsilon_c}} \tag{D10}$$

Similarly, raising power to the $1 - \epsilon_x$ and summing over j (D4) gives

$$\lambda_{1t} \left[\sum_{j=1}^{N} \zeta_j^x q_{jt}^{1-\epsilon_x} \right]^{\frac{1}{1-\epsilon_x}} = \lambda_{2t} r_{t+1} \chi_t. \tag{D11}$$

In addition, (D4) implies that

$$\sum_{j=1}^{N} q_{jt} x_{jt} = \frac{1}{\chi_t} \left[\sum_{j=1}^{N} \zeta_j^x q_{jt}^{1-\epsilon_x} \right]^{\frac{1}{1-\epsilon_x}} x_t = p_{xt} x_t, \tag{D12}$$

where

$$p_{xt} = \frac{1}{\chi_t} \left[\sum_{j=1}^{N} \zeta_j^x q_{jt}^{1-\epsilon_x} \right]^{\frac{1}{1-\epsilon_x}}. \tag{D13}$$

Therefore, we have p_{ct} and p_{xt}:

$$p_{ct} = \left[\sum_{j=1}^{N} \zeta_j^c q_{jt}^{1-\epsilon_c} \right]^{\frac{1}{1-\epsilon_c}} \quad \text{and} \quad p_{xt} = \frac{1}{\chi_t} \left[\sum_{j=1}^{N} \zeta_j^x q_{jt}^{1-\epsilon_x} \right]^{\frac{1}{1-\epsilon_x}} \tag{D14}$$

Now, it is enough to provide the relationship between productivity and price of industrial goods. (D24) implies that

$$\frac{q_{jt}}{q_{it}} = \frac{A_{it}}{A_{jt}}. \tag{D15}$$

Taken together with (D14) this implies

$$\frac{p_{xt}}{p_{ct}} = \frac{1}{\chi_t} \frac{\left[\sum_{j=1}^{N} \zeta_j^x q_{jt}^{1-\epsilon_x} \right]^{\frac{1}{1-\epsilon_x}}}{\left[\sum_{j=1}^{N} \zeta_j^c q_{jt}^{1-\epsilon_c} \right]^{\frac{1}{1-\epsilon_c}}} \tag{D16}$$

$$= \frac{1}{\chi_t} \frac{\left[\sum_{j=1}^{N} \zeta_j^x \left(\frac{A_{it}}{A_{jt}} q_{it} \right)^{1-\epsilon_x} \right]^{\frac{1}{1-\epsilon_x}}}{\left[\sum_{j=1}^{N} \zeta_j^c \left(\frac{A_{it}}{A_{jt}} q_{it} \right)^{1-\epsilon_c} \right]^{\frac{1}{1-\epsilon_c}}} \tag{D17}$$

$$= \frac{1}{\chi_t} \frac{\left[\sum_{j=1}^{N} \zeta_j^x A_{jt}^{\epsilon_x - 1} \right]^{\frac{1}{1-\epsilon_x}}}{\left[\sum_{j=1}^{N} \zeta_j^c A_{jt}^{\epsilon_c - 1} \right]^{\frac{1}{1-\epsilon_c}}}, \tag{D18}$$

which completes the proof.

Proof of Proposition 2. The proof follows from taking the derivative of (22) with respect to F.

D.2. *Omitted Derivations*

Entrepreneur's problem. First-order conditions for the entrepreneur's problem are given by (9), (10), and (11). Here, I show that $q_{jt}A_{jt} = \Gamma^*$, $l_{jt} = l^*$, and $k_{jt} = k^*$, given that $r_t = r$ and $w_t = w$. First, substituting (11) into the production function (4) yields

$$y_{jt} = A_{jt}\left(\frac{\alpha_z}{\psi}\right)^{\frac{\alpha_z}{1-\alpha_z}} l_{jt}^{\frac{\alpha_l}{1-\alpha_z}} k_{jt}^{\frac{\alpha_k}{1-\alpha_z}}. \tag{D19}$$

Then, by substituting the first-order conditions with respect to labor and capital, we obtain

$$q_{jt}y_{jt} = q_{jt}A_{jt}\left(\frac{\alpha_z}{\psi}\right)^{\frac{\alpha_z}{1-\alpha_z}} l_{jt}^{\frac{\alpha_l}{1-\alpha_z}} k_{jt}^{\frac{\alpha_k}{1-\alpha_z}} = \frac{w_t l_{jt}}{\alpha_l} = \frac{r_t k_{jt}}{\alpha_k}. \tag{D20}$$

Notice that in equilibrium it should be $\Pi_{jt}^E = 1$, for all j and t because the entrepreneur can enter any industry. Then, we have

$$\Pi_{jt}^E = q_{jt}y_{jt}(1-\alpha_l-\alpha_k-\alpha_z) = q_{jt}A_{jt}\left(\frac{\alpha_z}{\psi}\right)^{\frac{\alpha_z}{1-\alpha_z}} l_{jt}^{\frac{\alpha_l}{1-\alpha_z}} k_{jt}^{\frac{\alpha_k}{1-\alpha_k}}(1-\alpha_l-\alpha_k-\alpha_z) \tag{D21}$$

Since $q_{jt}y_{jt} = w_t l_{jt}/\alpha_l$ and $q_{jt}y_{jt} = r_t k_{jt}/\alpha_k$,

$$l^* = \frac{\alpha_l}{w(1-\alpha_l-\alpha_k-\alpha_z)} \tag{D22}$$

$$k^* = \frac{\alpha_k}{r(1-\alpha_l-\alpha_k-\alpha_z)}. \tag{D23}$$

Given this,

$$q_{jt}A_{jt} = \Gamma^* = (1-\alpha_l-\alpha_k-\alpha_z)^{-1}\left(\frac{\alpha_z}{\psi}\right)^{-\frac{\alpha_z}{1-\alpha_z}} (l^*)^{-\frac{\alpha_l}{1-\alpha_z}} (k^*)^{-\frac{\alpha_k}{1-\alpha_z}} \tag{D24}$$

Unconstrained researcher's problem. First, I simplify the expression for the return to the researcher from innovating intermediate good i, $\pi_{jt}(i)$, in equation (12). Substituting (11) into (12) yields

$$\pi_{jt}(i) = (\psi-1)z_{jt}(i) = \left(\frac{\alpha_z}{\psi}\right)^{\frac{1}{1-\alpha_z}} l_{jt}^{\frac{\alpha_l}{1-\alpha_z}} k_{jt}^{\frac{\alpha_k}{1-\alpha_k}} q_{jt}A_{jt}^*. \tag{D25}$$

Since $q_{jt}A_{jt}$, l_{jt}, and k_{jt} are identical across industries and over time in equilibrium. Therefore, we have

$$\pi_{jt}(i) = \frac{\pi}{a_{jt}}, \tag{D26}$$

where

$$\pi = (\psi - 1)\left(\frac{\psi}{\alpha_z}\right)^{\frac{1}{\alpha_z - 1}} (l^*)^{\frac{\alpha_l}{1-\alpha_z}} (k^*)^{\frac{\alpha_k}{1-\alpha_k}} \Gamma^*, \text{ and } \Gamma^* = q_{jt}A_{jt}, \ \forall\, j, t. \tag{D27}$$

Now, we are ready to solve the unconstrained problem of the researcher. The optimal innovation effort in the benchmark economy satisfies

$$\beta\pi = \kappa_j n'(\mu_j^*). \tag{D28}$$

If we assume $n(\mu_j) = -\log(1-\mu_j)$, then

$$\beta\pi = \frac{\kappa_j}{1-\mu_j^*}. \tag{D29}$$

Optimal industrial composition of final goods production. I analytically derive (18) and (19), which characterize the optimal industrial composition of final consumption and investment goods production. From (D3) we obtain

$$q_{jt}c_{jt} = p_{ct}c_t^{\frac{1}{\epsilon_c}} \left(\zeta_j^c\right)^{\frac{1}{\epsilon_c}} c_{jt}^{1-\frac{1}{\epsilon_c}}. \tag{D30}$$

Dividing both sides by $p_{ct}c_t$ yields

$$\frac{q_{jt}c_{jt}}{p_{ct}c_t} = \left(\zeta_j^c\right)^{\frac{1}{\epsilon_c}} c_t^{\frac{1-\epsilon_c}{\epsilon_c}} c_{jt}^{\frac{\epsilon_c - 1}{\epsilon_c}}. \tag{D31}$$

Notice that (D3) indicates

$$c_t^{\frac{1-\epsilon_c}{\epsilon_c}} = \left(\frac{q_{jt}}{p_{ct}}\right)^{1-\epsilon_c} c_{jt}^{\frac{1-\epsilon_c}{\epsilon_c}} \zeta_{jc}^{\frac{\epsilon_c - 1}{\epsilon_c}}. \tag{D32}$$

Substituting this expression into (D31) and using the definition of p_{ct} gives

$$\frac{q_{jt}c_{jt}}{p_{ct}c_t} = \left[\sum_{j=1}^{N} \frac{\zeta_{jc}}{\zeta_{ic}} \left(\frac{q_{it}}{q_{jt}}\right)^{\epsilon_c - 1}\right]^{-1}. \tag{D33}$$

An analogous argument using the first-order condition for investment and the definition of p_{xt} delivers the optimal industrial composition for investment (19).

Appendix E. Estimation Details

E.1. *Estimating σ and κ_j*

I calibrate the spillover parameter σ and the industry R&D efficiency parameters κ_j as follows.

- Step 1. Calculate the benchmark industry-level TFP growth rates by regressing the actual TFP growth rates on R&D intensity, and use the fitted values from this regression as the benchmark TFP growth rates g_i.
- Step 2. Given a set of g_i, use (16) to calculate μ_j^*.
- Step 3. Use the first order condition of the unconstrained researcher's problem to get κ_j.
- Step 4. Use (17) to calculate a_j.
- Step 5. Calculate model-implied R&D and choose σ and κ_j to minimize the sum of squared error of observed and model-implied R&D-intensity.

E.2. *Estimating Industrial Share Parameters and Elasticities of Substitution*

I estimate the industrial share parameters and the elasticities of substitution for final consumption and investment production using the optimal GMM, following the methodology of García-Santana et al. (2021). Unlike their cross-country estimation, I use U.S. data, as the objective is to isolate and quantify the direct impact of financial development on the rate of investment-specific technical change.

Notice that the optimal industrial composition of final consumption and investment depends on industrial prices, industrial share parameters, and elasticities of substitution:

$$\frac{q_{jt}c_{jt}}{p_{ct}c_t} = \left[\sum_{j=1}^{N} \frac{\zeta_j^c}{\zeta_i^c}\left(\frac{q_{it}}{q_{jt}}\right)^{\epsilon_c - 1}\right]^{-1} = f_i^c(\zeta^c, \epsilon_c, q_t) + \epsilon_{it}^c, \tag{E1}$$

$$\frac{q_{jt}x_{jt}}{p_{xt}x_t} = \left[\sum_{j=1}^{N} \frac{\zeta_j^x}{\zeta_i^x}\left(\frac{q_{it}}{q_{jt}}\right)^{\epsilon_x - 1}\right]^{-1} = f_i^x(\zeta^x, \epsilon_x, q_t) + \epsilon_{it}^x. \tag{E2}$$

Let $\Omega^c = \{\zeta_c, \epsilon_c\}$ and $\Omega^x = \{\zeta_x, \epsilon_x\}$ be vectors of parameters associated with final consumption and investment, respectively. Then, for each industry i the moment conditions are for final consumption and investment are given by:

$$E\left[\frac{\partial f_i^c}{\partial \Omega^c}\epsilon_{it}^c\right] = 0, \tag{E3}$$

$$E\left[\frac{\partial f_i^x}{\partial \Omega^x}\epsilon_{it}^x\right] = 0. \tag{E4}$$

I construct sample analogs of the moment conditions for each industry over the period 1947–2017 using U.S. data.