Financial Innovation and Endogenous Growth

Luc Laeven, Ross Levine, and Stelios Michalopoulos*

October 23, 2013

Abstract

We model technological and financial innovation as reflecting the decisions of profit-maximizing agents and explore the implications for economic growth. We start with a Schumpeterian model where entrepreneurs earn profits by inventing better goods and financiers arise to screen entrepreneurs. A novel feature is that financiers also engage in the costly, risky, and potentially profitable process of innovation: Financiers can invent more effective processes for screening entrepreneurs. Every screening process, however, becomes less effective as technology advances. The model predicts, therefore, that technological innovation and economic growth eventually stop unless financiers innovate to enhance screening. Empirical evidence supports this dynamic, synergistic model of financial and technological innovation and economic growth.

Keywords: Screening; Financial Intermediation; Invention; Economic Growth; Corporate Finance; Technological Change; Entrepreneurship.

JEL classification Numbers: G0; O31; O4

---

*Laeven: IMF and CEPR; Levine: Haas School of Business at the University of California, Berkeley, the Milken Institute, and the NBER; and Michalopoulos: Brown University and the NBER. We thank Giovanni Dell’Ariccia, Oded Galor, Peter Howitt, Yona Rubinstein, Frank Smets, Uwe Sunde, and seminar participants at the Brown University, the London School of Economics, the Bank of England, the Conference on Corporate Finance and Economic Performance at the University of St. Gallen, the University of Modena, Collegio Carlo Alberto, the European Central Bank, the American Economic Association meetings, and Stanford University for useful comments. The views expressed in this paper are entirely those of the authors. They should not be attributed to the International Monetary Fund.
1 Introduction

Two observations motivate this paper. First, a considerable body of research documents that technology and finance have evolved together, often in a synergistic manner, over several centuries (Allen and Gale, 1994; Frame and White, 2004; Goetzmann, 2009; Tufano, 2003). For example, to finance the construction of vast railroads in the 19th and 20th centuries, financial entrepreneurs developed specialized investment banks and accounting systems to facilitate screening and monitoring by distant investors (Chandler, 1965, 1977; Baskin and Miranti, 1997; and Neal, 1990). More recently, financial entrepreneurs developed modern venture capital firms to screen information technology start-ups. And, still more recently, financiers designed new financial institutions for identifying biotechnology endeavors with the highest probability of commercial success (Gompers and Lerner, 2001; Schweitzer, 2006). Econometric evidence from the United States (Amore, et al 2013; Chava et al 2013) and around the world (Beck et al 2013) suggests a strong connection between finance and technological innovation.

Second, economists have not yet developed models of the coevolution of technology and finance in which both technological and financial improvements reflect the actions of profit-maximizing agents. Existing Schumpeterian models of technological innovation examine the decisions of profit-maximizing technological entrepreneurs. These models provide crucial insights into how policies, laws, and regulations shape the incentives facing these technological entrepreneurs and hence the rate of technological change (Aghion and Howitt, 2009). But, researchers have not yet developed endogenous growth models in which profit-maximizing "financial entrepreneurs" choose how much to invest in the risky process of improving the financial system. Therefore, existing models cannot provide insights into how the incentives facing technological and financial entrepreneurs interact to shape the coevolution of technology and finance.

In this paper, we add two novel features to the canonical model of Schumpeterian growth, so that we can explore the endogenous, coevolution of finance and technology. First, we model both technological and financial innovation as reflecting the explicit, profit-maximizing choices of individuals. In textbook Schumpeterian models, technological entrepreneurs choose how much to invest in the risky activity of creating, enhancing, and adapting new goods and pro-

---

1 For example, in Bencivenga and Smith (1991), Levine (1991), and King and Levine (1993), finance influences the allocation of capital and long-run growth, but financial contracts, markets, and intermediaries neither emerge nor evolve endogenously with technology. In Greenwood and Jovanovic (1990) and Greenwood, Sanchez, and Wang (2010), the size of the financial changes with economic growth, but improvements in finance are not determined by agents choosing to invest in the risky process of financial innovation.
duction methods (Aghion and Howitt, 2009). Thus, technology evolves based on the endogenous choices of entrepreneurs. But, these models assume that the financial system is fixed. We relax this assumption. In our model, financial entrepreneurs choose how much to invest in the risky activity of improving the screening of technological entrepreneurs to identify the most promising ones. Thus, informational asymmetries evolve based on the endogenous choices of financiers. Investors will pay for the screening information produced by financiers if it increases the probability of investing in profitable technologies. Just as successful technological innovation generates temporary rents for the technological entrepreneur in textbook Schumpeterian models, successful financial "innovation" in our model generates temporary rents for financiers who are better at screening technological entrepreneurs than their competitors. Thus, financial entrepreneurs choose how much to invest in improving the screening of technological entrepreneurs based on the expected profits from this activity.

A second novel feature is that every screening modality becomes less effective at identifying promising entrepreneurs as technology advances. As technology moves up the Schumpeterian quality ladder, any particular screening procedure becomes less effective at identifying the technological entrepreneur with the best chance of successfully making the next technological improvement. That is, informational asymmetries widen endogenously as technologies advance. For example, the processes for screening the potential builders of new, cross-Atlantic ships in the 16th century were less effective at screening innovations in railroad technologies in the 19th century. Technological innovation makes existing screening technologies obsolete.

The core implications of the theory are that (1) technological and financial innovation will be positively correlated and (2) economic growth will eventually stagnate unless financiers innovate. In terms of positive synergies between technological and financial innovation, first note that technological change increases the returns to financial innovation. As technology advances, any given screening technology becomes less and less effective at identifying capable technological innovators. Thus, the benefits—and hence profits—to improving the screening technology grow as technologies advance. The synergies work in the other direction too. Better screening boosts the expected profits from technological innovation, because the expected returns from investing in technological innovation grow when financiers are better at identifying the most promising projects (innovators). In terms of stagnation, the model stresses that existing screening methods become increasingly inadequate at identifying promising technological innovations as the world’s technological frontier advances. Consequently, unless financiers innovate and improve screening technologies in tandem, the probability of finding successful
entrepreneurs falls toward zero, eliminating growth. With appropriate policies, laws, and regulations, however, the drive for profits by financial and technological entrepreneurs alike can produce a continuing stream of financial and technological innovations that sustain growth.

It is worth emphasizing and clarifying what this paper does and does not do. First, we examine the role of the financial system in screening entrepreneurs before they are funded. We do not model the role of the financial system in diversifying risk, easing transactions, monitoring loans, or enhancing the governance of firms once they are funded. Second, we use the term "financial innovation" to refer broadly to any change in the financial system that improves the screening of technological entrepreneurs. Thus, financial innovation is neither limited to the invention of new financial instruments, nor is it limited to innovation by financial institutions. Financial innovation includes more mundane financial improvements, such as the new financial reporting procedures that facilitated the screening and monitoring of railroads in the 19th century, improvements in data processing and credit scoring that enhanced the ability of banks to evaluate borrowers since the 1970s, and the adoption and upgrading of private credit bureaus around the world during the last few decades.

Although the main contribution of this paper is the development of a theoretical framework in which the profit-maximizing decisions of technological and financial entrepreneurs drive economic growth, we also examine the model’s predictions empirically. Our theory yields an estimation equation that differs in one key dimension from the textbook model of finance and growth (Aghion and Howitt, 2009): our theory predicts that the rate of financial system improvement affects the speed at which economies converge to the world economy frontier, while their model focuses on the level of financial development. Thus, we evaluate the comparative explanatory power of the level of financial development and financial innovation on an economy’s convergence to the economic leader’s growth path.

We primarily measure financial innovation by how quickly a country adopts a particular innovation associated with screening entrepreneurs. Specifically, we measure the year in which private agents create a credit bureau to share information about potential borrowers based on the data in Djankov et al. (2007). This empirical proxy is directly linked with the notion of financial innovation in our theoretical model, in which financiers invest in adapting and adopting better screening technologies. Pagano and Jappelli (1993) show that credit bureaus improve screening and credit allocation. In the regressions, we use the percentage of years between 1960 and 1995 in which a country has a private credit bureau to measure financial innovation, i.e., the speed with which countries adopt frontier screening technologies. Furthermore, since
our model stresses the role of private, profit-maximizing financial innovators, we conduct a placebo test and assess the impact of public credit registries. And, in robustness tests, we use several additional measures of financial innovation. Thus, our approach complements Beck, Chen, Lin, and Song (2012), who examine the relationship between economic growth and financial intermediary expenditures on research and development. We instead examine how quickly countries adopt a particular screening technology, along with other proxies of financial innovation, incorporate these proxies directly into the structural equation emerging from the theoretical model, and empirically assess the model’s predictions relative to those from a well-specified alternative model (Aghion, Howitt, and Mayer-Foulkes, 2005).

Consistent with the empirical prediction of our model, we find that, unlike the level of financial development, it is financial innovation that boosts the speed with which economies converge to the growth path of the economic leader. Furthermore, we find that unlike public credit registries it is the creation of private credit bureaus that boosts the rate of economic convergence. The results are robust to using instrumental variables to control for possible endogeneity and measurement error, and to controlling for many country characteristics. Although we discuss reasons for caution regarding these illustrative empirical results, the evidence is more consistent with our dynamic, synergistic model of financial and technological innovation than with existing theories of finance and growth.

Of course, financial development does not always promote economic growth, as suggested by the recent crisis, at least in the short run. Informational asymmetries between firms and financial intermediaries allow firms to extract rents from intermediaries, and financial intermediaries in turn may finance projects that are privately profitable but socially harmful.

\footnote{In assessing the impact of screening technologies on economic growth, our work differs from studies of how new financial products influence financial markets, as exemplified by Akhavein, Frame, and White (2005), Grinblatt and Longstaff (2000), Henderson and Pearson (2011), and the review by Frame and White (2004).}

\footnote{Indeed, many have sought to understand the role of financial innovation and excessive risk-taking by financial intermediaries in triggering the crisis. For example, recent economic theories suggest that financial innovation in conjunction with investors who neglect small risks (Gennaioli, Shleifer, and Vishny, 2012), investors with biased expectations or institutionalized constraints (Shleifer and Vishny, 2010), or excessively competitive banking markets (Thakor, 2012) can lead to financial and economic instability. And, Allen and Carletti (2006) presciently warned that financial innovations, such as securitization, that transfer credit risk can hinder the effective screening of borrowers, boosting financial fragility. Additionally, many have argued that agency problems arising from short-term oriented compensation contracts and conflicted rating agencies led to excessive risk taking by financial intermediaries (Acharya and Naqvi, 2012; Bolton, Freixas, and Shapiro, 2012). Consistent with these views, Dell’Ariccia, Igan, and Laeven (2012), Keys, Mukherjee, Seru, and Vig (2010), and Mian and Sufi (2009) find that securitization reduced lending standards and increased loan delinquency rates, while simultaneously boosting the supply of loans and financier profits (Loutsksina and Strahan, 2009), and Henderson and Pearson (2010) show that financial institutions engineered financial products that exploited investors’ misunderstanding of the payoffs to these products. Contrary to our paper, the focus of this literature is primarily on the short-run effects of financial innovation, not the long-run implications for economic growth.}
Indeed, it is straightforward to extend our model to allow for rent-seeking (as we do in the longer working paper version of this paper), so that financial innovations can be privately profitable but socially harmful. In the future, this framework can be further modified to include policy and other distortions that create incentives for financial innovations to increase financier profits at the expense of social welfare. From this perspective, our paper contributes toward the building of a more general, dynamic theory of endogenous growth, financial innovation, and financial regulation.

The remainder of the paper is organized as follows. Section 2 outlines the basic structure of the model, and Section 3 solves the model, determines the factors underlying steady-state growth, and derives testable implications. Section 4 takes the model to the data, and Section 5 concludes.

2 The Basic Structure of the Model

We begin with the discrete-time Schumpeterian growth model developed by Aghion, Howitt, and Mayer-Foulkes (2005). Economic activity occurs in $k$ countries, which do not exchange goods or factors of production, but do use each others’ technological ideas. There is a continuum of individuals in each country. Each country has a fixed population, $N$, which is normalized to one, so that aggregate and per capita quantities coincide. Each individual lives two periods and is endowed with three units of labor in the first period and none in the second. The utility function is linear in consumption, so that $U = c_1 + \beta c_2$, where $c_1$ is consumption in the first period of life, $c_2$ is consumption in the second period of life, and $\beta \in (0, 1)$ is the rate at which individuals discount the utility of consumption in period 2 relative to that in period 1.

2.1 Final Output

In every period the economy produces a final good combining labor and a continuum of specialized intermediate goods according to the following production function:

\[
Z_t = N^{1-\alpha} \int_0^1 A_{i,t}^{1-\alpha} x_{i,t}^\alpha di; \quad \alpha \in (0, 1),
\]

where $x_{i,t}$ is the amount of intermediate good $i$ in period $t$ with technology level of $A_{i,t}$. $N$ is the labor supply. The final good $Z$ is used for consumption, as an input into entrepreneurial and financial innovation, and an input into the production of intermediate goods.

The production of the final good, which we define as the numeraire, occurs under perfectly competitive conditions. Thus the price of each intermediate good equals its marginal product:
\[ p_{i,t} = \alpha \left( \frac{A_{i,t}}{x_{i,t}} \right)^{1-\alpha}. \]  

(2)

### 2.2 Intermediate Goods

In each intermediate goods sector \( i \), a continuum of individuals with an entrepreneurial idea is born in period \( t - 1 \). Only one entrepreneur in a sector has a capable idea, i.e., an idea with a positive probability of producing a successful innovation in period \( t \).

The quality of each entrepreneurial idea is unknown both to the entrepreneur and to households looking to invest in entrepreneurial ideas, which generates a demand for "screening." As we detail below, screening in a particular goods sector \( i \) is done either by households using a standard screening technology or by a financier who may improve upon the standard screening technology by successfully engaging in the costly, risky, and potentially profitable process of financial innovation. Based on the screening assessment, households fund the entrepreneur designated as capable.\(^4\)

Let \( \mu_{i,t}^e \) equal the probability that the capable entrepreneur successfully innovates, so that the level of technology of intermediate goods sector \( i \) in period \( t \), \( A_{i,t} \), is defined as:

\[
A_{i,t} = \begin{cases} 
\bar{A}_t & \text{with probability } \mu_{i,t}^e \\
A_{i,t-1} & \text{with probability } 1 - \mu_{i,t}^e 
\end{cases}
\]

(3)

where \( \bar{A}_t \) is the world technology frontier. Following the endogenous growth literature, technological innovation—or, more accurately, technological transfer—involves the costly, uncertain process of adapting ideas from the world technology frontier to the domestic economy. Innovation is necessary to transfer a technology because technology and technological expertise have tacit, country-specific qualities. Thus, when the capable entrepreneur successfully innovates, the level of technology jumps to \( \bar{A}_t \). This world technology frontier grows at a constant rate \( g \), which is taken as given for now (we derive it formally below).

A successful technological innovator enjoys a production cost advantage over entrepreneurs who do not innovate. Namely, she can produce intermediate goods at the rate of one unit

---

\(^4\)The assumption that entrepreneurs do not know whether their entrepreneurial idea is going to be profitable is important and well-documented. In the model, if entrepreneurs know that they have zero probability of successfully innovating, then they will not ask for funding because they only receive profits from a successful innovation. Hence, there would be no demand for financial screening. The historical examples presented above, along with work by Chernow (1990), Goetzmann and Rouwenhorst (2005), Gompers and Lerner (2001), Schweitzer (2006), and Tufano (2003), indicate that financiers provide information both to investors and entrepreneurs about the profitability of entrepreneurial ideas. For example, venture capitalists provide guidance to high-tech innovators about the marketability and value of their ideas.
of intermediate good per one unit of final good as input. Entrepreneurs who do not innovate can produce at the rate of one unit of intermediate good per $\chi$ units of final good as input, where $\chi > 1$. In every intermediate sector, there exists an unlimited number of people—the competitive fringe—capable of producing at the rate of one unit of intermediate good per $\chi$ units of the final good as input.

Thus, successful innovators become the sole producers in their respective intermediate sectors. They charge a price equal to the unit cost of the competitive fringe ($\chi$) and earn monopoly profits for one period. In intermediate goods sectors where entrepreneurial innovation is unsuccessful, production occurs under perfectly competitive conditions, so that the price equals the unit cost of the competitive fringe ($\chi$) and unsuccessful innovators earn zero profits. Thus, in all intermediate goods sectors, the price, $p_{it}$, equals $\chi$.

Successful innovators earn monopoly profits for one period. After that period, the incumbent monopolist dies and her technology can be imitated costlessly within the country. As stated above—and as emphasized throughout the endogenous growth literature, we assume that it is costly to transfer technologies from the world technology frontier to a particular country. Using the demand function for intermediate goods from equation (2), the quantity demanded for intermediate good $i$ equals:

$$x_{i,t} = \left(\frac{\alpha}{\chi}\right)^{\frac{1}{1-\alpha}} A_{i,t}.$$  \hfill (4)

Since profits per intermediate good equal $\chi - 1$, a successful innovator earns profits of:

$$\pi_{i,t} = \pi A_{i,t},$$

where $\pi = (\chi - 1) \left(\frac{\alpha}{\chi}\right)^{\frac{1}{1-\alpha}}$.  \hfill (5)

### 2.3 Financiers

There is a single financier in each sector that screens entrepreneurs to identify the capable one. In return to their screening services, financiers are paid a share of entrepreneurial profits which we describe formally below. Financiers provide their assessments to households and entrepreneurs, who use this information to make investment decisions. In the model, financiers are not organized in any particular institutional or legal form, such as a commercial bank, rating agency, or private equity firm; financiers are simply agents that screen entrepreneurial ideas. This fits both the real world, in which financiers organize in a variety of forms, and our broad conception of financial innovation, in which financiers create and modify their institutional and legal forms to screen entrepreneurs more effectively.
For each intermediate good sector $i$, there is a financier born each period $t - 1$. This financier may engage in financial innovation in order to improve the screening technology next period. A successful financial innovation in sector $i$ allows the financier to identify the capable entrepreneur in sector $i$ with probability one. In the absence of successful financial innovation, households use the existing, imperfect screening technology (the "standard" screening technology defined below) to select the capable entrepreneur.

Let $\mu_{i,t}^f$ equal the probability that a financier successfully innovates and improves the screening technology in sector $i$, so that the level of screening technology in intermediate goods sector $i$ in period $t$, $m_{i,t}$, is defined as:

$$m_{i,t} = \begin{cases} \bar{A}_t & \text{with probability } \mu_{i,t}^f \\ m_{t-1} & \text{with probability } 1 - \mu_{i,t}^f \end{cases}.$$  

(6)

For symmetry and simplicity of notation, we index the world screening frontier by the world technology frontier, $\bar{A}_t$. As the technological frontier advances, the frontier screening technology also advances, though the actual screening technology, $m_t$, may lag behind the frontier screening technology, $\bar{A}_t$. As with entrepreneurial innovation, financial innovation involves the costly and risky process of transferring screening methodologies from the world frontier to a particular country. As with intermediate goods technology, screening and financial expertise have tacit, country-specific qualities that must be addressed in adapting frontier screening technology to any particular country.

The successfully innovating financier in sector $i$ identifies the capable entrepreneur with probability one and is the monopolist provider of the frontier screening technology, $\bar{A}_t$. If unsuccessful, households can screen entrepreneurial ideas in sector $i$ during period $t$ using the common economy-wide screening technology of period $t - 1$, $m_{t-1}$. As with technological entrepreneurs, we assume that it is costless within a country to imitate the screening technology from last period, so that a successful financial innovator maintains the monopoly position for only one period.

Households in a country in period $t$ have free access to a common, economy-wide screening technology. We make the simplifying assumption that the latter equals the average of the screening technologies across all sectors in period $t - 1$, $m_{t-1}$. Mechanically, this assumption means that we do not have to keep track of the distance of each sector’s screening technology from the frontier; rather, we can simply trace the average distance from the frontier across all sectors in a country. The underlying intuition is that (a) last period’s screening technologies can be costlessly used by all sectors within a country and (b) when entrepreneurs in each sector try
to innovate to attain the world technology frontier, $\bar{A}_t$, such innovative activity involves using technological ideas from multiple sectors. For example, biotechnology innovation in period $t$ will typically involve the use of recent innovations in information technology, chemistry, and other sectors, so that screening biotech entrepreneurs in period $t$ requires an ability to screen technologies from these other sectors as well. Thus, the common screening technology in period $t$ is an amalgam of each sector’s screening technology from period $t-1$, which is freely available within the country in period $t$.

This assumption, however, is not qualitatively important. Rather than defining the common, economy-wide screening technology as the average of last period’s screening technologies, we could define the common, economy-wide screening technology as the maximum screening technology across all sectors in the last period. This yields the same qualitative predictions. Indeed, for the common, economy-wide screening technology, we could choose any point in the distribution of sector-specific screening technologies from last period without loss of generality. Furthermore, allowing each intermediate sector to maintain its own screening technology over time delivers cumbersome mathematics without altering the qualitative predictions.

The probability that the capable entrepreneur, $\lambda_{i,t}$, is identified in sector $i$ is a function of the gap between the level of the good’s frontier technology and the level of the screening technology. If the financier successfully innovates (which occurs with probability $\mu_{i,t}$), then there is no gap, and the financier identifies the capable entrepreneur with probability one. If the financier does not successfully innovate (which occurs with probability $1 - \mu_{i,t}$), then the financial gap in period $t$ reflects the difference between the technological frontier and last period’s common, economy-wide screening technology. In this case the probability that households correctly identify the capable entrepreneur is less than one. Specifically,

$$\lambda_{i,t} = \frac{m_{i,t}}{\bar{A}_t} = \begin{cases} \bar{A}_t/\bar{A}_t = 1 & \text{with probability } \mu_{i,t} \\ m_{t-1}/\bar{A}_t = \frac{\lambda_{t-1}}{1+g} & \text{with probability } 1 - \mu_{i,t} \end{cases}$$

where, as described above, $g$ is the growth rate of the world technology leader. Note that within a sector, households have the same screening technology and therefore identify the same entrepreneur as the capable one. Consequently, households finance only one entrepreneur per sector. Across sectors in which financiers did not successfully innovate, the households correctly identify the capable entrepreneur in $\lambda_t$ sectors, whereas in $1 - \lambda_t$ sectors, the households finance an incapable entrepreneur. Formally, screening projects by the households is deterministic within a sector but stochastic across sectors.

In the presence of technological innovation in the world frontier but in the absence
of domestic financial innovation, the screening technology becomes increasingly ineffective at identifying the capable entrepreneur. This growing financial gap reduces the probability that the society invests in the best entrepreneurial ideas with adverse ramifications on technological change. More formally, as technology advances (as $\bar{A}_t$ increases) and without a concomitant advance in the screening technology, $m_{i,t}$, the probability that households successfully identify and fund the capable entrepreneur, $\lambda_{i,t} = m_{i,t}/\bar{A}_t$, falls.

Financiers are paid by entrepreneurs in the form of a share, $\delta_{i,t}$, of entrepreneurial profits. For simplicity but without loss of generality we assume that, though all entrepreneurs sign a perfectly enforceable contract before screening regarding this share, only one entrepreneur in a sector is designated as capable by the financier when the latter innovates successfully. This designated entrepreneur, therefore, is the only one in the sector that receives capital from households.

The financier’s fraction of entrepreneurial profits, $\delta_{i,t}$, is determined endogenously in the model. In sectors with successful financial innovation, the successful financier is the sole provider of the frontier screening technology and charges a monopoly price in the form of a high share of entrepreneurial profits. That is, the successful, financier charges a price such that the entrepreneur is ex-ante indifferent between using the frontier screening technology and using the old screening technology available to the households. Without loss of generality, we assume that households can employ the old screening technology at zero cost, so that entrepreneurs screened by households keep 100% of the profits.

2.4 Timing of Events

At the beginning of period $t-1$ in each sector, the financier borrows money from households and invests in financial innovation. If the financier successfully innovates, then this new screening technology identifies the capable entrepreneur in the sector with probability one in period $t$. In this case entrepreneurs contract with her and she becomes the single seller of screening services in the sector. If the financier does not innovate, then the households screen the projects, using the old screening technology from period $t-1$, which is available at zero cost, and the entrepreneur designated as capable borrows from the households and invests in innovation.

In period $t$, uncertainty about entrepreneurial innovation is resolved. If the entrepreneur successfully innovates, she repays the households for their investment in innovation, pays the contracted fraction of profits to the financier, and keeps the remaining profits. If the financier and entrepreneur successfully innovate, then the financier pays back households who lent money
for financial innovation.

Figure 1 below summarizes all possible scenarios.

3 Innovation and Aggregate Growth

3.1 Entrepreneurial Innovation

The probability that a capable entrepreneur successfully innovates in period $t$, $\mu_{i,t}^e$, depends positively on the amount of resources invested in entrepreneurial innovation during period $t-1$, $N_{i,t-1}^e$, so that:

$$N_{i,t-1}^e = (\theta \mu_{i,t}^e) \gamma \bar{A}_t, \quad \gamma > 1.$$  

As in Aghion and Howitt (2009), the cost of entrepreneurial innovation in terms of final goods input increases proportionally with the world technology frontier, $\bar{A}_t$, so that it becomes more expensive to maintain an innovation rate of $\mu_{i,t}^e$ as the technology frontier advances. Moreover, $\theta$ is a an economy-wide constant reflecting institutional and other characteristics that affect the cost of innovation at every level of technological sophistication.

In equilibrium, each capable entrepreneur chooses $N_{i,t-1}^e$ to maximize expected profits. Given the contractual agreement between entrepreneurs and financiers, the entrepreneur designated as capable keeps the fraction $(1 - \delta_{i,t})$ of expected entrepreneurial profits $\Pi_{i,t}^e$, so that:

$$\Pi_{i,t}^e = (1 - \delta_{i,t}) \left( \beta \mu_{i,t}^e \pi \bar{A}_t - N_{i,t-1}^e \right).$$  

Risk-neutral individuals in the first period of life provide resources to entrepreneurs designated as capable by financiers. They provide resources to entrepreneurs at a sector-specific interest rate that is an inverse function of the quality of the screening technology in the sector. Defining the risk free interest rate as $r = 1/\beta - 1$, the interest rate charged to an

---

5We assume that all investment is domestically financed, but allowing for perfect international capital mobility would not change the analysis given the structure of the model. First, linear utility with a constant discount rate implies that individuals are indifferent between investing domestically or abroad, so that perfect capital mobility yields the same results. Second, we treat financial and technological innovation symmetrically: Entrepreneurs in a country must engage in the costly, risky process of adapting a technology from the frontier country to their domestic market. Similarly, financiers must engage in the costly, risky process of adapting a screening methodology from the frontier country to a particular domestic market. Whether the financier that undertakes these costly, risky "innovations" is domestic or foreign is irrelevant for our purposes.
entrepreneur that is rated as capable by a successful financer is \( R_{i,t}^e = \frac{1+r}{\lambda_{i,t} \mu_{i,t}} \). In turn, households charge the interest rate of \( R_{i,t} = \frac{1+r}{\lambda_{i,t} \mu_{i,t}} \) to entrepreneurs selected by the economy-wide screening technology from the last period. Recall that \( \lambda_{i,t} = 1 \) for financiers that successfully innovate, so these two interest rates are consistent.

Consider first entrepreneurs that are screened by successful financiers, so that the selected entrepreneur knows with probability one that she is the capable one. The profit-maximizing probability of entrepreneurial innovation comes from maximizing (9) by choosing \( \mu_{i,t}^e \) subject to (8):

\[
\mu_{i,t}^{e*} = \left( \frac{\beta \pi}{\gamma \theta \gamma} \right)^{1/(\gamma-1)},
\]

where we assume that \( \beta \pi < \gamma \theta \gamma \) to ensure that the equilibrium probability of successful entrepreneurial innovation is less than one \( (\mu_{i,t}^{e*} < 1) \) under perfect financial screening. Since entrepreneurs repay financiers only when they successfully innovate, \( \delta_{i,t} \) does not affect investment in entrepreneurial innovation.

From (10), the comparative statics of when a financer successfully innovates are intuitive. Entrepreneurs invest more in innovation and boost the probability of success when (1) the net profits per unit of the intermediate good, \( \pi \), are higher and (2) the cost of entrepreneurial innovation, \( \theta \), is lower. If \( \pi \) and \( \theta \) are common across sectors, then \( \mu_{i,t}^{e*} = \mu^{e*} \forall i \).

Substituting (10) into (9) yields the net expected profits of an entrepreneur screened by a successful financer,

\[
\Pi_{i,t}^{e*} = (1 - \delta_{i,t}) \mu_{i,t}^{e*} \varphi \bar{A}_t,
\]

where \( \varphi = \beta \pi (1 - 1/\gamma) \).

Now, consider entrepreneurs screened by households using the old, imperfect screening technology, \( m_{t-1} \). Under these conditions, the entrepreneur keeps all the profits, so that \( \delta_{i,t} = 0 \). Thus, the expected profits to an imperfectly screened entrepreneur, \( \Pi_{i,t}^{eg} \), i.e., the expected profits of an entrepreneur screened using the old screening technology is:

\[
\Pi_{i,t}^{eg} = \beta \lambda_{i,t} \mu_{i,t}^{e} \bar{A}_t - N_{i,t-1}^{e}.
\]

Consequently, the profit-maximizing probability of entrepreneurial innovation for imperfectly screened entrepreneurs, \( \mu_{i,t}^{e} \), is:

\[
\mu_{i,t}^{e} = (\lambda_{i,t})^{-\frac{1}{\gamma-1}} \mu^{e*}.
\]
Substituting (13) in (12) one derives the maximal net expected revenue of an entrepreneur selected using the old screening technology as:

$$
\Pi_{i,t}^e = (\lambda_{i,t})^{\gamma - \tau} \mu^{e*} \varphi A_t. \tag{14}
$$

The following Lemma establishes the properties of entrepreneurial innovation in sector $i$ when using the old screening technology, $\lambda_{i,t}$.

**Lemma 1** The properties of entrepreneurial innovation in sectors using the old, imperfect screening technology:

1. Entrepreneurs invest more in innovation and boost the probability of successful innovation when (1) the net profits per unit of the intermediate good, $\pi$, are higher and (2) the cost of entrepreneurial innovation, $\theta$, is lower, i.e.,

$$
\frac{\partial \mu_{i,t}^e}{\partial \pi} > 0, \quad \frac{\partial \mu_{i,t}^e}{\partial \theta} < 0.
$$

2. The rate of entrepreneurial innovation is an increasing function of the standard screening technology, $\lambda_{i,t}$, i.e.,

$$
\frac{\partial \mu_{i,t}^e}{\partial \lambda_{i,t}} > 0.
$$

**Proof.** These properties follow by directly differentiating equation (13). \qed

We can now derive the fraction of entrepreneurial profits accruing to the entrepreneur $(1 - \delta_{i,t})$ and the financier $(\delta_{i,t})$. For the unscreened entrepreneurs in the beginning of period $t - 1$ to be indifferent between choosing a contract with a financier or using the economy-wide screening technology supplied by the households, these two alternatives must deliver the same expected profits. Formally, (11) must equal (14), so that:

$$
\delta_{i,t} = 1 - (\lambda_{i,t})^{\gamma - \tau}. \tag{15}
$$

Equation (15) indicates that the better is the economy’s financial screening capacity (higher $\lambda_{i,t}$) the lower is the fraction of entrepreneurial profits $(\delta_{i,t})$ that a successful financier can demand. This occurs because if the standard screening technology is close to the frontier screening technology, then households offer a close substitute. On the other hand, if the available screening technology is a poor substitute for newly developed screening capabilities, then the financier can obtain a larger fraction of expected entrepreneurial profits.
3.2 Financial Innovation

As with entrepreneurial innovation, the probability that the financier in sector $i$ successfully innovates during period $t - 1$ and identifies the entrepreneur capable of innovation in period $t$, $\mu_{i,t}^f$, depends positively on the amount of resources invested in financial innovation during period $t - 1$, $N_{i,t-1}^f$:

$$ N_{i,t-1}^f = (\theta_f \mu_{i,t}^f)^\gamma \bar{A}_t, \quad \gamma > 1, \quad (16) $$

where the cost of financial innovation in terms of the final goods input increases proportionally with the world technology frontier, $\bar{A}_t$. Thus, it becomes more expensive to maintain the same rate of financial innovation, $\mu_{i,t}^f$, as the technological frontier advances since the entrepreneurs that are screened by financiers are striving to reach the world technology frontier.

The financier chooses $N_{i,t-1}^f$ to maximize expected profits, $\Pi_{i,t}^f$. Since a successfully innovating financier keeps the fraction $\delta_{i,t}$ of expected entrepreneurial profits, $\Pi_{i,t}^e$, the financier’s expected profits equals:

$$ \Pi_{i,t}^f = \mu_{i,t}^f \beta \delta_{i,t} \Pi_{i,t}^e - N_{i,t-1}^f. \quad (17) $$

The financier maximizes profits by borrowing $N_{i,t-1}^f$ worth of final goods and investing these resources in financial innovation. Risk-neutral individuals lend to financiers seeking to innovate at an interest rate of $R_{i,t}^f = \frac{1+r}{\mu_{i,t}^f \mu_{i,t}^e}$, which is a function of the risk free interest rate, $r$, the probability that the financier successfully innovates, and the probability that the entrepreneur designated by the financier as capable successfully innovates. After substituting (15) into (17), the financier chooses to borrow and invest in financial innovation such that the profit-maximizing probability of successful financial innovation in sector $i$ during period $t$ is:

$$ \mu_{i,t}^{f*} = \left( \frac{\beta \mu_{i,t}^e \varphi(1 - (\lambda_{i,t} \gamma_{i,t}^{\gamma-1}))}{\gamma \theta_f^{\gamma-1}} \right)^{\frac{1}{\gamma-1}}, \quad (18) $$

where we assume that $\theta_f > \theta$ to ensure that the rate of financial innovation is less than one.

3.3 Aggregating the Financial System

To examine the efficiency of a country’s financial system, we aggregate across individual sectors to focus on the average, or representative, probability that the capable entrepreneur is identified,

$$ \lambda_t = \int_0^1 \lambda_{i,t} di, $$
where \( \lambda_{i,t} \) equals the probability that the entrepreneur capable of innovating in sector \( i \) during period \( t \) is chosen. From equation (7), the average level of financial efficiency evolves according to the following equation:

\[
\lambda_t = \mu_t^f + (1 - \mu_t^f) \frac{\lambda_{t-1}}{1 + g}.
\]

(19)

Financiers identify the capable entrepreneur with probability one in fraction \( \mu_t^f \) of the sectors in which the financial innovation is successful. Since we aggregate financial screening quality across a continuum of sectors, we ignore negligible relative size differences. In the remaining \( 1 - \mu_t^f \) of the sectors, households identify the capable entrepreneur with a probability of \( \frac{\lambda_{t-1}}{1 + g} < 1 \).

To obtain the steady state level of average financial screening, let \( \lambda_t = \lambda_{t-1} = \lambda^* \) and \( \mu_t^f = \mu^f \) in the steady state and then solve for \( \lambda^* \) in equation (19):

\[
\lambda^* = \frac{\mu^f}{g + \mu^f}.
\]

(20)

Directly differentiating equation (20) yields a key result:

\[
\frac{\partial \lambda^*}{\partial \mu^f} > 0.
\]

(21)

The higher is the steady state rate of financial innovation, \( \mu^f \), the more efficient is the economy’s financial system at identifying capable entrepreneurs in the steady state, \( \lambda^* \).

The steady state profit-maximizing innovation probability of the financial system is determined by replacing \( \lambda_{i,t} = \lambda^* \) into (18), so that:

\[
\mu^f = \left( \frac{\beta \mu^e \varphi (1 - (\lambda^*)^{\frac{1}{\gamma - 1}})}{\gamma \theta_j} \right)^{\frac{1}{\gamma - 1}}.
\]

(22)

Finally, combining (20) and (22), yields the implicit function:

\[
F(\mu^e, \mu^f, \theta_j) \equiv 0,
\]

(23)

which characterizes the equilibrium innovation rate of the financial system. The following Lemma summarizes the properties of an economy’s financial innovation rate:

**Lemma 2** The properties of financial innovation in the steady state:

1. Financial innovation is an increasing function of the rate at which entrepreneurs innovate:

\[
\frac{\partial \mu^f}{\partial \mu^e} > 0.
\]
2. Financial innovation is a decreasing function of the costs of financial innovation, $\theta_f$:
\[
\frac{\partial \mu_t^{f*}}{\partial \theta_f} < 0.
\]

3. Financial innovation is an increasing function of the rate at which the world technology frontier, $g$, advances:
\[
\frac{\partial \mu_t^{f*}}{\partial g} > 0.
\]

**Proof.** Repeated differentiation of equation (22) according to the Implicit Function Theorem delivers the results.

We present the comparative statics of $\mu_t^{f*}$ with respect to entrepreneurial innovation $\mu^{e*}$ to highlight the nexus between entrepreneurial and financial innovation. It is straightforward to show that since $\mu^{e*}$ itself is a function of exogenous features of the economy ($\theta, \pi$), (part 1 of Lemma 1), changes in these structural parameters will affect the equilibrium financial innovation accordingly.

Stagnant entrepreneurial innovation reduces the expected profits from financial innovation, which in turn (a) reduces investment in financial innovation, (b) slows the rate of improvement in the screening technology, (c) lowers the probability that capable entrepreneurs are selected, and hence (d) impedes technological innovation and growth. Put differently, there is a multiplier effect associated with changes in entrepreneurial innovation that reverberates through the rate of financial innovation back to the rate of technological change.

Policies, regulations, and institutions that impede financial innovation have large effects on the rate of technological innovation. Thus, countries in which it is more expensive to innovate financially (higher $\theta_f$) will tend to experience slower rates of technological growth. Cross-economy differences in the cost of financial innovation can arise for many reasons. For example, a large literature suggests that some legal systems (for example, those that rely on case law) are more conducive to financial innovation than other systems (such as those that rely less heavily on case law to adapt to changing conditions), which has been documented by Levine (2005b), Gennaioli and Shleifer (2007), and Levine (2005a, 2005b).

### 3.4 Aggregate Economic Activity

This section aggregates an economy’s economic activity and examines its components. We define the economy’s average level of technological productivity, $A_t$, as:
\[
A_t = \int_0^1 A_t(i) di,
\]
where aggregation is performed across the continuum of intermediate sectors.

To derive the law of motion of the average level of technological productivity, note that in equilibrium, the expected rate of entrepreneurial and financial innovation is the same across sectors, i.e. \( \mu_{i,t}^f = \mu^f_t \) and \( \mu_{i,t}^e = \mu^e_t \). Then, one can simply use the branches of Figure 1 and equation (13) to derive the law of motion of average productivity:

\[
A_{t+1} = (\mu_{t+1}^f \mu_{t+1}^e + (1 - \mu_{t+1}^f) \lambda_{t+1}^{1/(\gamma-1)} \mu_{t+1}^e) \tilde{A}_{t+1} + (1 - \lambda_{t+1}^{1/(\gamma-1)} \mu_{t+1}^e - \mu_{t+1}^f \mu_{t+1}^e + \mu_{t+1}^f \lambda_{t+1}^{1/(\gamma-1)} \mu_{t+1}^e) A_t.
\]

Inspecting (24) reveals that a country’s average technological productivity in period \( t + 1 \) is a weighted average of sectors that implement the frontier technology, \( \tilde{A}_{t+1} \), and of sectors using the average technology of period \( t \), \( A_t \). The weights are functions of (a) the rate of financial innovation, \( \mu_{t+1}^f \), (b) the quality of the financial screening technology, \( \lambda_{t+1} \), and (c) the probability of successful entrepreneurial innovation, \( \mu_{t+1}^e \). In particular, the productivity parameter will equal \( \tilde{A}_{t+1} \) both in sectors where financiers and entrepreneurs successfully innovated and in sectors where financiers did not innovate, but where, nevertheless, the funded entrepreneurs successfully innovated.

To derive the per capita gross domestic product within a country, note that it is composed of wages in the final goods sector and profits in the intermediate goods and financial sectors. In terms of wages, note that final good production can be summarized by \( Z_t = \zeta A_t \) where \( \zeta = (\alpha/\chi)^{\alpha/(1-\alpha)} \), which may be derived by substituting (4) into (1). Since by assumption the final goods sector is competitive, the wage rate \( w_t \) is the marginal product of labor in the production of the final good, so that \( w_t = (1 - \alpha) Z_t = (1 - \alpha) \zeta A_t \).

In terms of profits, successful entrepreneurs earn \( \pi \tilde{A}_t \), where \( \pi = (\chi - 1) \left( \frac{\alpha}{\chi} \right)^{1/(1-\alpha)} \). Thus, per capita gross domestic product is the sum of added value across sectors:

\[
Y_t = w_t + \mu_t \pi_t = (1 - \alpha) \zeta A_t + \mu_t \pi \tilde{A}_t,
\]

where \( \mu_t \) is the fraction of goods’ sectors with successful entrepreneurial innovation in period \( t \).

\text{\footnotesize \(^6\)Unlike Aghion et al. (2005), where the proportionality of the wage rate to the domestic productivity determines the level of technology investment in a credit-constrained country, this ratio plays no role in determining entrepreneurial investment in our model. As shown in equations (10) and (13), the probability of entrepreneurial innovation depends only on entrepreneurial profits and the level of the financial screening technology. Domestic productivity determines the amount that a financier and an entrepreneur can borrow from households in period \( t \). Since we assume that neither financiers nor entrepreneurs can hide their proceeds, households are willing to lend any amount at the prevailing interest rate.}
3.5 Equilibrium Economic Performance Across Countries

We now characterize the growth rate of $Y_t$ as a function of the underlying parameters of the model economy. Denote a country’s inverse distance from the world technological frontier as $a_t = A_t/A_t$. Each economy takes the evolution of the frontier as given (see below how this is derived). Thus, the technology gap evolves according to:

$$a_{t+1} = (\mu^f_{t+1} \mu^e_{t+1} + (1-\mu^f_{t+1})\lambda_{t+1}^{1/(\gamma-1)} \mu^e_{t+1}) + \frac{(1 - \lambda_{t+1}^{1/(\gamma-1)} \mu^e_{t+1} - \mu^f_{t+1} \mu^e_{t+1} + \mu^f_{t+1} \lambda_{t+1}^{1/(\gamma-1)} \mu^e_{t+1})}{1 + g} a_t \equiv H(a_t).$$ (26)

This converges in the long run to the steady state value:

$$a_{ss} = \frac{(1 + g) \mu^*}{g + \mu^*},$$

where $\mu^* = \mu^{f*} \mu^{e*} + (1 - \mu^{f*}) (\lambda^{1/(\gamma-1)} \mu^{e*}$ is the fraction of innovating entrepreneur sectors.

As in other multi-country Schumpeterian models, the growth rate of the technological frontier is determined by the equilibrium rate of entrepreneurial innovations in the leading country labeled 1.\(^7\) That is,

$$g = \mu^{f*} \mu^{e*} + (1 - \mu^{f*}) (\lambda^{1/(\gamma-1)} \mu^{e*}.$$(27)

The following Proposition summarizes the properties of an economy attempting to implement the world technology frontier.

**Proposition 1** An economy’s steady state technology gap displays the following properties:

1. The steady state technology gap is decreasing at the cost of financial innovation, $\theta_f$, i.e.,

$$\frac{\partial a_{ss}}{\partial \mu^{f*}} \frac{\partial \mu^{f*}}{\partial \theta_f} < 0.$$  

2. The steady state technology gap is increasing at the rate of entrepreneurial innovation, $\mu^{e*}$, i.e.,

$$\frac{\partial a_{ss}}{\partial \mu^{e*}} \frac{\partial \mu^{e*}}{\partial \theta} < 0, \quad \frac{\partial a_{ss}}{\partial \mu^{e*}} \frac{\partial \mu^{e*}}{\partial \pi} > 0.$$ 

\(^7\)There is no need to explicitly specify the size of innovation for the leader since it does not affect the equilibrium innovation probability. To see that, assume that the leader’s technological jump from period $t-1$, is $h > 1$, i.e. $A_t = hA_{t-1}$. Looking at (9) it becomes clear that the size of the jump, $h$, multiplies both the expected revenues and the innovation costs leaving the equilibrium rate of entrepreneurial innovation unaffected.
Proof. The first property obtains by differentiating $a_{ss}$ with respect to $\mu^{fs}$ and taking into account the second part of Lemma 2. The second property obtains by taking into account that both the net profits per unit of the intermediate good, $\pi$, and the cost of entrepreneurial innovation, $\theta$, (see part 1 of Lemma 1) shape entrepreneurial innovation which in turn determines the steady state technological gap.

**Corollary 1** An economy blocking financial innovation will eventually stagnate irrespective of the initial level of screening technology, $\lambda_t$.

$$a_{ss} = 0 \text{ if } \theta_f \to \infty.$$  

**Proof.** When the cost of financial innovation goes to infinity, $\theta_f \to \infty$, then part 2 of Lemma 2 implies that financial entrepreneurs allocate no resources towards R&D and thus financial and subsequently technological innovation stagnate.

The next section briefly discusses the derived properties.

### 3.6 Dynamic versus Static Financial Markets

The model economy predicts that regardless of the screening capability of the financial system in period $t$, $\lambda_t$, anything that prohibits financial innovation will eventually stop economic growth as illustrated in Figure 2a.

![Figure 2a: Static Financial Markets](image1)

![Figure 2b: Dynamic Financial Markets](image2)

Initially, the consequences of impeding innovation may have negligible effects on the rate of entrepreneurial innovation if the initial efficiency of the screening technology is high. Inevitably, however, as the world technology frontier advances and renders the initial screening technology increasingly obsolete, the absence of financial innovation produces a large and growing gap between actual and potential growth.

Graphically, this scenario is equivalent to the $H(a_t)$ curve in Figure 2b shifting downwards over time in the absence of financial innovation–with $H(a_t)$ given by equation (26). Eventually, the $H(a_t)$ curve hits the origin as in Figure 2a. This financially induced poverty trap is not caused by standard credit constraints. Rather, it arises because financiers fail to innovate and improve the screening technology in tandem with the world-technology frontier. Introducing
financial innovation in such a dormant financial system will boost growth, allowing for convergence to the world growth rate. It is straightforward to show this by verifying that the per capita gross domestic product in a financially innovating economy, i.e. }^{f\ast} > 0, derived in (25), grows at the rate of the world technology frontier.

Due to the synergies between financial and entrepreneurial innovation, interventions in either sector have an amplifying effect on the economy’s innovation rate. For instance, among economies that invest in financial innovation, further decreasing the barriers to financial innovation will shift the }^2(a_t) curve upwards in Figure 2b, increasing a country’s steady state level of technology relative to the frontier, }_ss. In a similar fashion, factors affecting entrepreneurial innovation also shape a country’s steady state technology gap.

4 Financial Innovation and Growth Convergence: Some Cross-Country Empirical Evidence

In this section, we evaluate a key feature of our model that differs from existing models of financial development and growth: Economies without financial innovation will stagnate, irrespective of the initial level of financial development.

This can be tested by extending the Aghion, Howitt, and Mayer-Foulkes (2005), henceforth AHM, regression framework to include not only measures of financial development but also financial innovation. In particular, first consider the AHM cross-country regression framework:

\[ g - g_1 = b_0 + b_1 F + b_2 (y - y_1) + b_3 F (y - y_1) + b_4 X + u, \]  

\[ (28) \]

where } - }_1 is average growth rate of per capita income relative to U.S. growth over the period 1960-95, } is financial development in 1960, which is measured as credit to the private sector as a share of GDP, } - }_1 is log of per capita income relative to U.S. per capita income, } is set of control variables, and } is an error term.

AHM estimate this regression model using cross-sectional data on 63 countries over the period 1960-1995. The data are from Levine, Loayza, and Beck (2000), who found a positive, large, and robust effect of financial intermediation on economic growth. Consistent with their theoretical model, AHM find that }_1 is not significantly different from zero and that }_3 is negative and significant. Thus, they find that financial development accelerates the rate at which economies converge to the technological leader.

In contrast to AHM, our model stresses the importance of financial innovation, not financial development. Indeed, in our model the level of financial development in any period
is an outcome of previous financial innovations. Building on our model above, we amend the AHM regression framework as follows:

\[ g - g_1 = b_0 + b_1 F + b_2(y - y_1) + b_3 F(y - y_1) + b_4 X + b_5 f + b_6 f(y - y_1) + u, \]  

(29)

where \( f \) denotes financial innovation over the sample period 1960-95. Our model predicts that \( b_6 < 0 \) : the likelihood and speed of convergence depends positively on financial innovation. The model also predicts that \( b_5 \) will be insignificant, indicating a vanishing steady-state growth effect. This prediction derives from the assumption that the technological leader already possesses a financial system that innovates at the growth-maximizing rate, so that faster financial innovation would not increase the probability of picking capable entrepreneurs. Note that \( f \) is measured over the sample period, while \( F \) is measured at the beginning of the sample period.

We first measure financial innovation in a country by how quickly the country adopts a particular innovation associated with screening borrowers, namely the sharing of information about creditors through a private bureau. This proxy for financial innovation is directly linked with improvements in screening technology, which is the notion of financial innovation in our theoretical model. Specifically, we measure financial innovation, \( f \), as the fraction of years between 1960 and 1995 that a private credit bureau was in place. We obtain data on the year of establishment of a private credit bureau from Djankov et al. (2007).

Private credit bureaus are organizations that provide credit information on individuals and firms. They are commonly established by private banks to share credit information about the creditworthiness of borrowers. The world's oldest private credit bureau, Equifax, was founded in Atlanta, Georgia in 1899 as Retail Credit Company. It began with two brothers, Cator and Guy Woolford, keeping a list of customers and their creditworthiness for their local Retail Grocer's Association. They would sell their book to other merchants in the association and credit reporting was born. With the onset of credit scoring models, developed by engineer Bill Fair and mathematician Earl Isaac in the late 1950s who founded the Fair Isaac Corporation (producer of the well-known FICO credit scores) and the passage of the 1968 Fair Credit Reporting Act in the US, private credit bureaus became an increasingly important provider of credit information.

Such bureaus allow banks to obtain credit information on customers of other banks and serve as an important screening mechanism for new borrowers. It is true that these credit bureaus are backward looking; they provide information on a potential borrower's credit history. But, this information is used in evaluating the economic potential of entrepreneurs. Indeed, the
growing availability of credit information following the advance of private credit bureaus and credit scoring models and the reduced cost in processing this information due to improvements in information technology have enhanced the ability of banks to screen borrowers, especially small firms (Petersen and Rajan, 2002). Thus, we use the establishment of a private credit bureau as one proxy for "financial innovation". As of 2003, private credit bureaus operated in 55 out of the 133 countries covered by Djankov et al. (2007).

Theoretical and empirical research emphasizes both the importance of information in shaping the allocation of credit and the particular role of credit bureaus in enhancing information dissemination and hence the functioning of the financial system. Consistent with information-based theories of credit allocation (e.g., Stiglitz and Weiss, 1981), Pagano and Jappelli (1993) find that the existence of a credit registry is an important factor in determining credit availability. Djankov et al. (2007) show that the establishment of private credit bureaus is especially useful in explaining cross-country differences in financial development.

We exploit an additional, testable implication of the model by examining public credit registries. Credit information sharing arrangements can also be organized by the government (typically the central bank) in the form of a public credit registry, which provides an additional testable hypothesis. Although, in principle, such government-owned credit registries can deliver the same type of credit information as private credit bureaus, these public registries are not suitable empirical proxies for the private, profit-maximizing financial innovators that are the focus of our theoretical model. Private credit bureaus usually gather more information and offer a broader range of services to lenders than public credit registries according to Jappelli and Pagano (2002). For example, the New Zealand private bureau offers credit scoring, borrower monitoring, and debt collection services, in addition to traditional credit history information. Thus, we also empirically test the differential impact of private credit bureaus vís a vís public credit registries on economic growth.

As a second alternative measure of financial innovation, we use the average growth rate of financial development, $F$, over the period 1960-95. This is a catch-all measure of financial innovation that simply measures the change in financial development over our sample period. However, we prefer the measure of financial innovation based on establishing a private credit bureau because it is more closely linked to the mechanisms underlying financial innovation in our model.

For comparison purposes, we test the empirical predictions of our model using the same dataset and the same set of control variables, $X$, as in Levine et al. (2000) and AHM. These
control variables include measures of educational attainment (school), government size (gov), inflation (pi), black market premium (bmp), openness to trade (trade), revolutions and coups (revc), political assassinations (assass), and ethnic diversity (avelf). The summary statistics of our main regression variables, including data definitions, are reported in Table 1.

We follow Levine et al. (2000) and AHM in using private credit to GDP as our preferred measure of financial development. This is the value of credits by financial intermediaries to the private sector, divided by GDP, and excludes credit granted to the public sector and credit granted by the central bank and development banks. We also report results below using alternative measures of financial development, including the ratio of liquid liabilities of banks to GDP and the ratio of bank assets to GDP (following Levine et al. (2000) and AHM), an index of creditor rights (following Djankov et al., 2007), and an index of accounting standards.

We start by running a simple cross-country OLS regression, limiting the sample to countries with data on the initial level of financial development in 1960. This limits the sample to 56 countries, as compared to AHM who use average private credit over the period 1960-95. Our results are unaltered when we use average private credit. We prefer to use the initial level of private credit because it is more tightly linked to the theoretical model and because using the initial value helps distinguish between financial development and the rate of financial innovation during the sample period. The regression results from estimating equation (28) are presented in the first column of Table 2. These regression results confirm the AHM findings of a negative interaction between financial development, \( F \), and the deviation of initial per capita income from US per capita income, \((y - y_1)\). The estimated value of \( b_1 \) is not significantly different from zero and the estimated value of \( b_3 \) is negative and statistically significant.

Next, we estimate equation (29), which incorporates financial innovation. Thus, we evaluate the role of financial innovation in driving the speed of convergence of economies to the growth path of the technological leader. The sample reduces to 51 countries due to missing data on the screening innovation variable. These results are reported in column 2 of Table 2.

Consistent with the central empirical prediction from our model, the interaction between financial innovation, \( f \), and deviation of growth from U.S. growth \((y - y_1)\) is negative and significant. The estimated value of \( b_5 \) (the coefficient on \( f \)) is not statistically different from zero, but the estimated value of \( b_6 \) (-1.70, which is the coefficient on \( f(y - y_1) \)) is negative and statistically significant. Thus, when incorporating financial innovation, the level of financial development does not help explain growth convergence, but financial innovation helps account for the speed of convergence when conditioning on many other factors, including the level of
financial development and its interaction with initial income differentials.

The economic effect of this result is large. A one-standard-deviation increase in financial innovation (0.39) implies an increase in growth relative to U.S. growth \((g - g_1)\) for a country’s whose initial per capita income is one standard deviation below that of the U.S. of about 0.53. This is large since the standard deviation of the growth differential with the U.S. in the sample is about 1.7. In other words, the effect amounts to about one-third the standard deviation in growth differentials.

Next, we run two sets of instrumental variables (IV) regressions to address concerns about endogeneity between growth, financial development and financial innovation. We follow AHM, instrumenting for \(F\) and \(F(y - y_1)\) using legal origin, \(L\), and legal origin interacted with initial relative output \((L(y - y_1))\). Legal origin is a set of three dummy variables, first used by La Porta et al. (1997, 1998), indicating whether the country’s legal system is based on French, English, German, or Scandinavian traditions. La Porta et al. (1997, 1998) argue that legal origin explains variation in the protection of the rights of shareholders and creditors. Levine et al. (2000) argue that legal origin constitutes a good set of instruments for financial development because they are predetermined variables, have a bearing on the enforceability of financial contracts, and have a strong effect on financial development, and should affect growth primarily though their impact on financial development.

As an instrument for financial innovation, \(f\), we use a measure of the degree of financial reforms that ease restrictions on the operation of the financial system, which in turn encourages financiers to invest more in innovation to enhance screening and less in rent-seeking activities. Specifically, we use the change over the period 1973-1995 in the Abiad and Mody (2005) financial reform index, \(R\), as instrument for \(f\), and instrument \(f(y - y_1)\) using \(R(y - y_1)\). Abiad and Mody (2005) create an aggregate country-level index of financial reform for a sample of 35 countries over the period 1973-1996 by aggregating six subcomponents that each obtain a score between 0 and 3, with higher scores denoting more liberalization. The six policy components relate to credit controls, interest rate controls, entry barriers in the banking sector, operational restrictions, privatization in the financial sector, and restrictions on international financial transactions. We use the relative change in this aggregate index over the period 1973-1995 as proxy for financial deregulation at the country level.

Using an index of financial liberalization as an instrument for financial innovation is motivated by research on how deregulation in the U.S. banking industry enhanced financial innovation and efficiency. For example, Silber (1983) and Kane (1983 and 1988) argued that fi-
financial deregulation was an important underlying force behind U.S. financial sector innovations in the 1970s and early 1980s, while Jayaratne and Strahan (1998) find that the U.S. banking industry became significantly more efficient following financial deregulation during the 1980s. They show that non-interest costs fell, wages fell, and loan losses fell after states deregulated branching.

Our identification strategy hinges on the validity of our choice of instruments. To test the strength of our instruments, we use $F$-tests of joint significance of the excluded instruments in the first stage regressions of $F$, $F(y - y_1)$, $f$, and $f(y - y_1)$. Further to tests the validity of the overidentifying restrictions, which imply that the instruments do not affect growth through any channel other than financial innovation, we perform the Sargan $J$-test of overidentifying restrictions, whose null hypothesis is that the instruments are uncorrelated with the residuals in the instrumental variable regressions. If our instruments were affecting growth through an omitted variable, then the Sargan test would reject the null hypothesis.

Column (3) of Table 2 presents instrumental variable regression results. The instruments for the financial development terms, $F$ and $F(y - y_1)$, are the same as in AHM, and we add corresponding instruments for the financial innovation terms, $f$ and $f(y - y_1)$. Specifically, as instruments for financial development and financial innovation we use legal origin dummy variables of the country and the change over the period 1973-1995 in the Abiad and Mody (2005) financial reform index. Furthermore, for the interactive terms, $F(y - y_1)$ and $f(y - y_1)$, we use as instruments the interactions of the initial real per capita GDP gap with the United States $(y - y_1)$ and both the legal origin dummy variables and the change in the financial reform index. The presumption here is that countries with financial systems that remain financially repressed do not innovate and improve their screening technologies and other financial practices.

The IV results are fully consistent with those from the OLS specification, and both the statistical and economic significance of the effect of $f(y - y_1)$ on growth differentials increases in size. The first-stage regressions are very strong, rejecting the null hypothesis that the instruments do not explain variation in the endogenous variables at the one percent level, and the Sargan test of overidentifying restrictions supports the choice of our instruments. Importantly, adding our measure of financial innovation to the AHM specification reduces the economic and statistical significance of financial development in explaining the rate at which economies converge to the technological leader.

While the choice of financial deregulation as an instrument for innovation is supported by the $F$-test of excluded instruments and the Sargan test of overidentifying restrictions, some
concern remains about the validity of this instrument. The change in the financial reform index is not a predetermined variable. Unlike the legal origin variables, it captures deregulation over the sample period. Moreover, improvements in technology could also have triggered demand for financial reform.

To address these concerns, in column (4), we drop financial development and use the legal origin dummy variables as instruments for financial innovation, while also including as instruments the interactions between the legal origin dummy variables and the initial real per capital GDP gap with the United States. Using legal origin as an instrument for financial innovation (instead of financial development) is motivated by the work by Levine (2005b), Gennaioli and Shleifer (2007), and Djankov et al. (2007), who argue that the common law legal system promotes financial innovation. Again, the first-stage regressions reject the null hypothesis that the instruments do not explain \( f \) and \( f(y - y_1) \), and the Sargan test of overidentifying restrictions supports the use of our instruments.

As a further test of the model’s predictions, we evaluate whether—and confirm that—the effects of \( f \) and \( f(y - y_1) \) on per capita GDP growth operate through productivity growth, as implied by the theory, rather than by only affecting physical capital accumulation. To this end, we re-estimate equation (35) using the difference in productivity growth relative to that in the U.S. as the dependent variable instead of per capita GDP growth differentials. And, we replace log per capita in 1960, \( y \), with the log of aggregate productivity in 1960, \( p_y \). We obtain data on productivity in 1960 and productivity growth over the period 1960-1995 from Benhabib and Spiegel (2005). Productivity growth is measured by the Solow residual. The results presented in Table 3 are similar to those obtained using the per capita GDP growth variable. Specifically, the interaction between \( f \) and \( (y - y_1) \) still enters negatively and significantly in all equations, with magnitudes similar to those obtained in Table 2. As before, the tests for validity and strength of the instruments continue to support our choice of instruments.

Thus far, the results are consistent with the view that financial innovation shapes the rate of growth convergence, but other factors could affect convergence. Perhaps, it is not financial innovation per se; perhaps, countries fail to converge in growth rates because of a lack of education (or because financial innovation matters for growth only because it facilitates investment in education). Or, perhaps other factors affect convergence, which are not already captured by the initial level of GDP or financial innovation. We address these questions by considering whether the effect of financial innovation on growth convergence is robust to considering alternative convergence channels by including interaction terms between \( (y - y_1) \) and
the host of country characteristics included in $X$. The results, estimated using instrumental variables, are presented in Table 4.

We find that our main results are robust to controlling for a wide range of other potential convergence channels, as captured by the term $X(y - y_1)$. In all cases, the estimated sign of the coefficient on $f(y - y_1)$ remains negative and statistically significant, and other than the interaction with the black market premium variable and the ethnic diversity variable, none of the other channels considered obtains a statistically significant coefficient. Our instruments continue to be supported by the $F$-test of excluded instruments and the Sargan $J$-test of overidentifying restrictions.

The results also hold when using these alternative measures of financial development, as reported in Table 5. The first alternative measure is the ratio of liquid liabilities to GDP, where liquid liabilities equals currency plus demand and interest bearing liabilities of banks and non-bank financial intermediaries. The second alternative measure is the ratio of bank assets to GDP, where bank assets exclude credit from non-bank financial intermediaries. Creditor rights is an index of the protection of creditor rights, first developed and collected by La Porta et al. (1998) and updated by Djankov et al. (2007). Our main results on financial innovation ($b_5 = 0$ and $b_6 < 0$) are robust to using alternative measures of financial development.

Finally, Table 6 considers alternative measures of financial innovation that more closely capture the screening technologies available to financial intermediaries in the country. For comparison purposes, the regression in column (1) of Table 6 replicates our earlier results in column (3) of Table 2. In column (2) of Table 6, we use the fraction of years during the period 1960-95 a public credit registry was in place as alternative measure of financial innovation. As explained earlier, our prior is that this not a good measure of private sector induced financial innovation, as public credit registries are established and owned by governments (not the private sector). Moreover, public credit registries generally offer a narrower range of services to lenders compared to private credit bureaus. They merely offer information without additional services such as credit scoring techniques that allow lenders to reap the full benefits of such information in terms of improving their screening technology.

Consistent with our priors, we find that the establishment of public registries does not have a significant growth convergence effect but private credit bureaus are associated with faster convergence rates. The coefficient on the interaction between the public registry variable and $(y - y_1)$ enters with a positive coefficient that is statistically not different from zero (column 2). But, as already discussed, the coefficient on the interaction between the private credit bureau
and initial income differences enters with a significant negative coefficient (column 1).

The last column of Table 6 uses the growth rate in the ratio of private credit to GDP over the period 1960-95 as proxy for financial innovation. As emphasized above, this alternative measure has several shortcomings. Nevertheless, we continue to find a positive effect of financial innovation on growth convergence when measuring financial innovation using the increase in financial development over the sample period. The interaction term between $f$ and $(y - y_1)$, with $f$ measured as the growth in the ratio of private credit to GDP over the period 1960 to 1995, enters with a negative coefficient of -0.31 that is statistically significant at 1%, consistent with our main results that use the screening-based measure of financial innovation.

These empirical analyses structured directly by the model presented above, provide evidence consistent with the theory’s predictions, and contribute to several new empirical papers on financial innovation and growth. Amore et al (2013) find that improvements in finance increase the flow of credit to patent-creating firms in the United States, suggesting that finance fosters technological innovation. Chava et al (2013) show that banking reforms across the states of the United States that intensified competition among banks boosted the rate of innovation among young, private firms. We contribute to this work by showing that the rate at which countries adopted a particular improvement in the mechanisms for screening firms is strongly, positively associated with the rate of economic growth in way that is fully consistent with the general equilibrium model of financial and technological innovation presented above.

5 Concluding Remarks

Historically, financial innovation has been a ubiquitous phenomenon of expanding economies. Whether it is the development of new financial instruments, the formation of new financial institutions, or the emergence of new financial reporting techniques, successful technological innovations have typically required the invention of new financial arrangements. In this paper, we model the joint, endogenous evolution of financial and technological innovation, focusing on improvements in screening technologies of financiers.

We model technological and financial innovation as reflecting the profit-maximizing decisions of individuals and explore the implications for economic growth. We start with a Schumpeterian endogenous growth model where entrepreneurs can earn monopoly profits by inventing better goods. Financiers screen the potential entrepreneurs. More importantly, they engage in the costly and risky process of inventing better processes for screening entrepreneurs. Successful financial innovators are more effective at screening entrepreneurs than the
standard screening methods available. Their increased efficiency generates monopoly rents and the economic motivation for financial innovation. Every particular screening process becomes obsolete as technology advances. Consequently, technological innovation and economic growth will eventually stop unless financiers innovate.

The predictions emerging from our model, in which financial and technological entrepreneurs interact to shape economic growth, fit cross-country data better than existing models of financial development and growth. Rather than stressing the level of financial development, we highlight the vital role of financial innovation in the process of economic growth. From a policy perspective, the analyses stress adaptability and innovation as key elements for sustaining economic growth. Institutions, laws, regulations, and policies that impede financial innovation slow technological change and economic growth.
References


