Financial Innovation and Endogenous Growth

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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 is more consistent with this dynamic, synergistic model of financial and technological innovation than with existing theories of finance and growth.

Keywords: Invention; Economic Growth; Corporate Finance; Technological Change, Entrepreneurship.

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1 Introduction

Since the financial turmoil of 2007-2009 was associated with the widespread use of novel financial products, many have sought to understand the role of financial innovation 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. 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 (Loutskina 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.

In this paper, we take a step back from these vital questions concerning the recent crisis and financial innovation and instead focus on the long-run relationship between financial innovation and economic growth. Our goals are to develop a theoretical model of the endogenous, coevolution of finance and technology that accounts for broad historical patterns and also to provide an initial empirical assessment of the predictions emerging from the model.

The broad historical narrative is that financial system improvements have been integrally connected to technological change and economic growth for several millennia. About six thousand years ago, the Sumerian city of Uruk blossomed as tradable debt contracts emerged to facilitate a diverse assortment of intertemporal transactions underlying specialization, innovation, and growth (Goetzmann, 2009). In ancient Rome, private investors developed the critical features of limited liability companies, including tradable shares, and corporations that owned property and wrote contracts independently of the individual shareholders. The creation of these corporations eased the mobilization of capital for new, large-scale mining technologies (Malmendier, 2009). To finance the construction of vast railroads in the 19th and 20th centuries, financial entrepreneurs developed specialized investment banks and improved accounting

systems to foster screening and monitoring by distant investors (Baskin and Miranti, 1997; and Neal, 1990). Credit bureaus were first established in 1899 to collect and share information on customer’s creditworthiness. These bureaus have been improved and adapted to the specific conditions of countries around the world, enhancing the allocation of capital (Pagano and Jappelli, 1993; and Djankov, McLiesh, and Shleifer, 2007). Over the last couple of centuries, financiers have developed products to mitigate agency concerns and informational asymmetries impeding the financing of frontier technologies (Allen and Gale, 1994; Tufano, 2003; Frame and White, 2004). More recently, financial entrepreneurs modified venture capital firms to screen high-tech inventions and then adapted these arrangements to support biotechnology endeavors (Gompers and Lerner, 2001; Schweitzer, 2006).

Yet, models of economic growth generally ignore financial system improvements and instead take the financial system as given and inert. Most frequently, financial arrangements are added to core models of endogenous growth developed by Romer (1990) and Aghion and Howitt (1991). For example, in King and Levine (1993), the financial system affects the rate of technological change by determining the frequency with which society allocates funds to those entrepreneurs with the highest probability of successfully innovating. In Bencivenga and Smith (1991) and Levine (1991), finance influences long-run growth by affecting the risk of investing in high-return projects. In these models, however, financial contracts, markets, and intermediaries neither emerge nor evolve endogenously with technological change.

Even in models where the size of the financial system changes as the economy develops, the same profit motives that underlie technological innovation do not spur modifications to the financial system. In Greenwood and Jovanovic (1990), financial intermediaries produce information about investment projects and thereby improve capital allocation. Since there is a fixed cost to joining financial intermediaries, growth means that more individuals can afford to join financial intermediaries, which boosts the efficiency of capital allocation and economic growth. Thus, economic growth and membership in the financial intermediary evolve together. In Greenwood, Sanchez, and Wang (2010), financial intermediaries invest resources to monitor firms. When financial institutions invest more resources, this enhances capital allocation and accelerates growth. Yet, in these models, improvements in the effectiveness of the monitoring technology are not determined by agents choosing to invest in the risky process of financial innovation. In this sense, therefore, finance remains exogenously given.

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 production methods (Aghion and Howitt, 2009). 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 and identifying the most promising ones. Investors will pay for the information produced by screening 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 continuously choose how much to invest in improving the screening of technological entrepreneurs.

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. 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, which enhances the returns to developing improved screening methods. Thus, financial and technological innovations are inextricably linked: financial frictions evolve endogenously based on the decisions of profit maximizing financial and technological entrepreneurs.

Two central, interrelated 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. Technological change increases the returns to financial innovation, and better screening boosts the expected profits from technological innovation. There are dynamic synergies between finance and technology. In the absence of financial innovation, existing screening methods become increasingly obsolete as technological innovation continues, so that the probability of identifying successful entrepreneurs falls toward zero, eliminating growth. Financiers, however, can avoid economic stagnation by creating more effective screening modalities. Therefore, the drive for profits by financial and technological entrepreneurs alike, can produce a continuing stream of innovations that sustain growth.
Two features of our model are worth emphasizing and clarifying. First, like existing models of finance and growth, we focus on one—and only one—function performed by the financial system. In our model, as in Greenwood and Jovanovic (1990), King and Levine (1993), and Galetovic (1996), the financial system screens entrepreneurs before they are funded. We do not model the role of the financial system in diversifying risk, easing transactions, or enhancing the governance of firms once they are funded, which are considered individually by Bencivenga and Smith (1991), Greenwood, Sanchez, and Wang (2010), and others. Unlike existing models of finance and growth, however, we endogenize the dynamic choice of financiers to invest in improving one key function performed by the financial system.

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 also 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 model 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 with 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).\footnote{In assessing the impact of financial innovation 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).}

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 the creation of private credit bureaus boosts the rate of economic convergence, but the formation of public credit registries does not. 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 innovation does not always promote growth, as suggested by the recent crisis. Indeed, extending our model to allow for rent-seeking illustrates that financial innovations that are privately profitable for financiers are 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 provides historical examples of the importance of financial innovation. Section 3 outlines the basic structure of the model, and Section 4 solves the model, determines the factors underlying steady-state growth, and derives testable implications. Section 5 takes the model to the data, and Section 6 concludes.
2 Historical Examples and Motivation

In this short subsection, we provide a few historical examples to illustrate the synergistic ties between financial and technical innovation and motivate key features of the formal model that we develop below. In particular, these examples suggest that (1) financial innovations that improve the screening of entrepreneurs boost the rate of technological innovation and hence economic growth; (2) technological innovation, in turn, creates opportunities for financiers to earn profits by further enhancing their screening capabilities to assess the next wave of technological advances; and (3) effective screening by financiers not only helps investors identify entrepreneurs with the most promising ideas, screening also provides information to entrepreneurs about the potential profitability of their ideas. Put differently, effective screening provides information to investors and entrepreneurs. The examples highlight the endogenous coevolution of financial and technological innovation.

Consider first the financial impediments to railroad expansion in the 19th century. The financial innovations that fostered improvements in ship design and oceanic explorations in the 16th - 18th centuries were ineffective at screening and funding innovations in steam-powered railroads in the 19th century (Baskin and Miranti, 1997). While holding out the promise of extraordinary profits, railroads were a new, complex technology. Severe informational asymmetries made it difficult for investors to screen and monitor railroads, which impeded investment. Given these informational problems, prominent local investors with close ties to those operating the railroad were initially the primary sources of capital for railroads (Chandler, 1954, 1965, 1977). This reliance on local finance, however, restricted the growth and profitability of railroads and, therefore, limited investment in improving railroad technology.

So, financiers innovated. Since problems with screening railroads impeded profitable investments, profit-seeking financiers arose to mitigate these problems (Baskin and Miranti, 1997, p. 137-138). Specialized financiers and investment banks emerged to mobilize capital from individuals, screen and invest in railroads, and monitor the use of those investments, often by serving on the boards of directors of railroad corporations (Carosso, 1970). In the United States, several major investment banking houses, such as J.P. Morgan & Company and Kuhn-Loeb & Company, became experts at evaluating railroads. Based on their expertise and reputation, they mobilized funds from wealthy investors, evaluated proposals from railroads, allocated capital, and oversaw the operations of railroad companies for investors. As explained by Chernow (1990), these bankers not only helped investors fund promising railroads, they also provided useful information to railroad entrepreneurs. Besides facilitating an increase in track
mileage, financial innovation fostered investment in creating faster, more comfortable, and safer trains (Chandler, 1977).

Financiers also improved accounting and financial reporting methods, which both helped the railroad firms and facilitated the screening and monitoring of railroads by investors. As documented by Chandler (1965, 1977), the geographical size and complexity of railroads forced financiers to pioneer new procedures for collecting, organizing, and assessing price, usage, breakdown, and repair information. While these accounting and reporting innovations boosted the operational efficiency of the railroads, these financial tools also made it easier for outside investors to evaluate railroads, fostering investment and innovation in railroads (Baskin and Miranti, 1997, p. 143-145).

This example of how improvements in the financial system facilitated railroad expansion is not meant as an argument that financial innovation only involves improvements in screening or even that improvements in screening were the most crucial spurs to railroad expansion. Investment banking and better reporting methods reduced information and transactions costs, which eased the ex-post monitoring of railroads. We simply note that these financial innovations also made it easier to screen railroads, which in turn made it easier to mobilize capital to improve and expand railroads.

But, the financial innovations that fostered the success of railroads were incapable of fueling the innovations in information processing, telecommunications, and biotechnology during the last 30 years. Indeed, as nascent high-tech information and communication firms struggled to emerge in the 1970s and 1980s, traditional commercial banks were reluctant to finance them because these new firms did not yet generate sufficient cash flows to cover loan payments and the firms were run by scientists with no experience in operating profitable companies (Gompers and Lerner, 2001). Conventional debt and equity markets were also wary because the technologies were too complex for investors to evaluate. There was a problem: Potentially profitable high-tech firms could not raise sufficient capital because the existing financial system could not screen them effectively.

Besides reducing informational asymmetries, financial innovations helped railroads in other ways. New financial instruments, and the expanded use of existing securities, eased financial constraints on railroads, reduced the risk of bankruptcy from short-term reductions in income, and customized the risks facing potential investors in railroads, all of which combined to increase investment in railroads (Baskin and Miranti, 1997, p. 146-157; Tufano, 1997, p. 20-28). By providing a menu of securities with different characteristics, railroads greatly expanded the range of outside investors favorably disposed to purchase railroad securities. In this paper, we focus only on financial innovations that reduce informational asymmetries. Clearly, other forms of financial innovation also shape investment in technological change as suggested by Goetzmann and Rouwenhorst’s (2005) masterful discussion of financial innovations throughout history.
So, financiers innovated. Venture capital firms arose to screen entrepreneurs and provide technical, managerial, and financial advice to new high-technology firms. In many cases, venture capitalists had become wealthy through their own successful high-tech innovations, which provided a basis of expertise for evaluating new entrepreneurs. In fact, venture capitalists often had more information about the potential profitability of an embryonic technology than the initiating innovators themselves. Thus, venture capitalists provided guidance to innovators, while also attracting additional capital from outside investors. In terms of funding, venture capitalists typically took large, private equity stakes that established a long-term commitment to the enterprise, and they generally became active investors, taking seats on the board of directors and helping to solve managerial and financial problems. Motivated by profits, financiers innovated by creating venture capitalist institutions to better screen and finance high-tech firms.

Again, these examples of improvements to the financial system that fostered advancements in information technologies do not suggest that financial innovation only involved screening. Clearly, venture capital firms also facilitated the management and corporate governance of firms, which were crucial to technological change. But, improvements in the ex-ante screening of technological entrepreneurs were a vital component of these "financial innovations" that eased the financing of these technologies.

These examples highlight the synergistic relationship between finance and technology. As described by Adam Smith, the very essence of economic growth involves increased specialization and the use of more sophisticated technologies. Thus, economic growth, technological change, and greater complexity are inextricably linked. The increased complexity, however, makes it more difficult for the existing financial system to screen the ideas of budding entrepreneurs. Economic progress itself, therefore, makes the existing financial system less effective. Without a commensurate improvement in the financial system, the quality of screening falls, slowing the rate of technological innovation. But, this dynamic also creates opportunities for financiers. Financiers can earn profits by developing improved screening methods that foster investments in profitable, frontier technologies. We now develop a model to capture this intuition formally.

3 The Basic Structure of the Model

3.1 Preliminaries

$k$ countries, which do not trade, but do use each others’ technological ideas.

Each country has a fixed population, $N$, which is normalized to one.

Each individual lives two periods
Each individual is endowed with three units of labor in the first period and none in the second.

\[ U = c_1 + \beta c_2. \]

### 3.2 Final Output

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

\( x_{i,t} \) is the amount of intermediate good;
\( A_{i,t} \) is the technology level;
\( Z_t \) is consumed, used as input into innovation & intermediate goods production.

The production of the final good (the numeraire) occurs under perfectly competitive conditions, so that the price of each intermediate good equals its marginal product:

(2) \[ p_{i,t} = \alpha \left( \frac{A_{i,t}}{x_{i,t}} \right)^{1-\alpha}. \]

### 3.3 Intermediate Goods

1. In each intermediate goods sector \( i \), a continuum of individuals with an entrepreneurial idea is born in period \( t - 1 \).

2. Only one has a "capable" idea.

3. \( \mu_{i,t}^e \) equals the probability that the capable entrepreneur successfully innovates.

4. The quality of each idea is unknown both to the entrepreneur and households. This generates a demand for "screening."

5. The level of technology of intermediate goods sector \( i \) in period \( t \), \( A_{i,t} \), is defined as:

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

where \( \bar{A}_t \) is the world technology frontier.
3.4 Production of intermediate goods

Successful innovators can produce one unit of intermediate good with one unit of final good as input.

Unsuccessful innovators can produce one unit of intermediate good with \( \chi \) units of final good as input, where \( \chi > 1 \).

There is an unlimited number of people at this competitive fringe.

A successful innovator in \( i \) becomes the sole producer in \( i \), and charges a price equal to the unit cost of the competitive fringe (\( \chi \)).

In intermediate goods sectors where innovation is unsuccessful, production occurs under perfect competition, so that price, \( p_{it} \), equals \( \chi \).

3.4.1 Production of intermediate goods

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

Since profits per intermediate good equal \( \chi - 1 \), a successful innovator in sector \( i \) earns profits of:

(5) \( \pi_{i,t} = \pi \tilde{A}_{i,t} \), where \( \pi = (\chi - 1) \left( \frac{\alpha}{\chi} \right)^{\frac{1}{1-\sigma}} \).

3.5 Financiers

1. Financiers screen entrepreneurs to find the capable one.

2. Financiers are paid a share of entrepreneurial profits.

3. Financiers provide their assessments to households and entrepreneurs.

Financiers screen and households fund entrepreneurial innovation.

4. Without screening, innovative activity ceases because households are unwilling to provide resources to a non-screened entrepreneurs since the probability of the project being successful is of measure zero.

5. Households do not invest in entrepreneurs that financiers designate as "incapable."

6. Financiers are simply agents that screen entrepreneurial ideas.
3.5.1 Financial innovation

1. One capable financial innovator in each sector $i$ in $t - 1$.

2. A successful financial innovation in sector $i$ allows the financier
to identify the capable entrepreneur in sector $i$ with probability one.

3. In the absence of successful financial innovation, financiers might
designate the wrong entrepreneur as capable,
and the economy invests in the wrong entrepreneur.

4. 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 in $i$ in period $t$, $m_{i,t}$, is defined as:

\[
(6) \quad m_{i,t} = \begin{cases} 
A_t & \text{with probability } \mu_{i,t}^f \\
\ r_{i,t} & \text{with probability } 1 - \mu_{i,t}^f 
\end{cases}.
\]

We index the world screening frontier
by the world technology frontier, $A_t$.

3.5.2 Financial innovation

\[
(6) \quad m_{i,t} = \begin{cases} 
A_t & \text{with probability } \mu_{i,t}^f \\
\ r_{i,t} & \text{with probability } 1 - \mu_{i,t}^f 
\end{cases}.
\]

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, $A_t$.

As with entrepreneurial innovation, financial innovation involves
the costly and risky process of transferring screening methodologies
from the world frontier to a particular country.
3.5.3 Successful and unsuccessful financial innovation

1. As with intermediate goods technology, screening has
country-specific qualities that must be addressed in
adapting frontier screening technology to any particular country.

2. The successful financial innovator identifies the capable entrepreneur
with probability one and is the monopolist provider of screening.

3. An unsuccessful financial innovator becomes part of a competitive fringe
that can screen in sector $i$ during period $t$ using the common economy-wide
screening technology of period $t - 1$, $m_{t-1}$.

4. 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.

3.5.4 Some assumptions on the mechanics

5. We assume that everyone in a country in period $t$
has free access to a common screening technology that equals
the average across all sectors in period $t - 1$, $m_{t-1}$.

5.a. 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 use the average distance from the frontier across all sectors.

5.b. Intuitively:
(i) last period’s screening technologies can be costlessly used by all sectors and
(ii) innovative activity involves using technological ideas from multiple sectors.
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 in $t$.

5.c. Qualitatively, unimportant assumption:
(i) 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.

(ii) Indeed, we could choose any point in the distribution of sector-specific screening technologies.

(iii) Furthermore, allowing each intermediate sector to maintain its own screening technology over time delivers a cumbersome analysis without changing the model’s qualitative predictions.

3.5.5 Financial and technological innovation: "gap"

The probability that the financier in sector $i$ correctly identifies the capable entrepreneur, $\lambda_{i,t}$, is a function of the gap between the technology and screening.

If the financier successfully innovates (which occurs with probability $\mu_{i,t}^f$), then there is no gap: the financier identifies the capable entrepreneur.

If the financier does not successfully innovate then there is a gap between technology and screening. The financier sometimes identifies the wrong entrepreneur as capable.

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

where, as described above, $g$ is the growth rate of the world technology leader.

Discussion of the "gap" 1. In the presence of technological innovation in the world frontier but in the absence of domestic financial innovation, the screening technology becomes increasingly ineffective, i.e., $\lambda_{i,t} = m_{i,t} / \tilde{A}_t$, falls.

1.a. People increasingly invest in the wrong entrepreneurs

1.b. technological change slows

1. c. growth slows
**Financier compensation** 1. Financiers are paid by entrepreneurs in the form of a share, $\delta_{i,t}$, of entrepreneurial profits.

2. All screened entrepreneurs sign a perfectly enforceable contract regarding this share
   2.a. only one entrepreneur in $i$ is designated as capable.
   2.b. This entrepreneur is the only one that receives capital from households.

3. $\delta_{i,t}$ is determined endogenously in the model.
   3.a. The financier that successfully innovates is the sole provider of the frontier screening technology and charges a monopoly price in the form of $\delta_{i,t}$.
   3.b. The successful, monopolist financier charges a price such that the entrepreneur is indifferent between using the frontier screening technology or the competitive fringe.
   3.c. We assume that the perfectly competitive fringe can provide the old screening technology at zero cost, so that entrepreneurs using the competitive fringe of financers keep 100% of the profits.

### 3.6 Timing of Events

1. At the beginning of $t - 1$ in each sector of each country, the capable financier borrows money from households and invests in financial innovation.
   1.a. If successful, this new screening technology identifies the capable entrepreneur with probability 1 in period $t$ and this financier becomes the monopolist screener.
   1.b. A competitive fringe of financers that can provide screening using the old screening technology from $t - 1$.

2. Unscreened entrepreneurs solicit screening from financers.
   2.a. As we show, if a financier innovates, entrepreneurs contract with her.
2.b. Or entrepreneurs use the competitive fringe.

3. The entrepreneur designated as capable by a financier borrows from households and invests in innovation.

4. In period $t$, uncertainty about innovation is resolved.

4.a. If the entrepreneur successfully innovates, she repays the households, pays the financier, and keeps the remaining profits.

4.b. If the financier and entrepreneur successfully innovate, the financier pays households who lent for financial innovation.

4 Innovation and Aggregate Growth

4.1 Entrepreneurial Innovation

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

\[ (8) \quad N_{i,t-1}^e = (\theta \mu_{i,t}^e) \gamma \bar{A}_t, \quad \gamma > 1. \]

As in Aghion and Howitt (2009), the cost of innovation in terms of final goods increases with the technology frontier, so that it becomes more expensive to maintain an innovation rate of $\mu_{i,t}^e$ as the technology advances.

$\theta$ reflects institutional characteristics that affect the cost of innovation.

4.1.1 Profit maximizing innovators

In equilibrium, each capable entrepreneur chooses $N_{i,t-1}^e$ to maximize expected profits.

Given contracts between entrepreneurs and financiers, the entrepreneur designated as capable keeps $(1 - \delta_{i,t})$ of expected entrepreneurial profits $\Pi_{i,t}^e$, so that:
(9) $\Pi_{i,t}^e = (1 - \delta_{i,t}) \left( \beta \mu_{i,t} \pi \tilde{A}_t - N_{i,t-1}^e \right)$.

Maximize (9) subject to (8)

Risk-neutral individuals in the first period of life provide loans to entrepreneurs designated as capable by financiers. They charge a sector-specific interest rate:

$$R_{i,t}^e = \frac{1 + r}{\lambda_{i,t} \rho_{i,t}}$$

to entrepreneurs.

Recall that $\lambda_{i,t} = 1$ for financiers that successfully innovate

4.1.2 Solving technological innovation problem

Consider entrepreneurs screened by successful financiers.

Maximize (9) subject to (8).

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

where we assume that $\beta \pi < \gamma \theta^*$ so that the probability of successful entrepreneurial innovation is less than one under perfect financial screening.

Since entrepreneurs repay financiers only when they innovate, $\delta_{i,t}$ does not affect investment in entrepreneurial innovation.

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.

Substituting ...

(11) $\Pi_{i,t}^{e*} = (1 - \delta_{i,t}) \mu^{e*} \varphi \tilde{A}_t$,

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

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4.1.3 Solving technological innovation problem

Consider entrepreneurs screened by the competitive fringe using the old, imperfect screening technology, \( m_{t-1} \).

Thus, the entrepreneur keeps all the profits, so that \( \delta_{i,t} = 0 \).
The expected profits to an imperfectly screened entrepreneur, \( \Pi_{i,t}^{e'} \):

\[
\Pi_{i,t}^{e'} = \beta \lambda_{i,t} \mu_{i,t}^{e'} \pi \hat{A}_t - N_{t-1}^e.
\]

The profit-maximizing probability of entrepreneurial innovation for imperfectly screened entrepreneurs, \( \mu_{i,t}^{e'} \), is:

\[
\mu_{i,t}^{e'} = (\lambda_{i,t}) \mu^{e*}.
\]

Substituting yields

\[
\Pi_{i,t}^{e'} = (\lambda_{i,t}) \mu^{e*} \varphi \hat{A}_t.
\]

4.1.4 The properties of entrepreneurial innovation

**Lemma 1**

1. Entrepreneurs invest more in innovation and boost the probability of innovation when (1) expected profits, \( \pi \), are higher and (2) the cost of 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 innovation is an increasing function of the screening technology, \( \lambda_{i,t} \), i.e.,

\[
\frac{\partial \mu_{i,t}^{e'}}{\partial \lambda_{i,t}} > 0.
\]

3. For the unscreened entrepreneurs in \( t - 1 \) to be indifferent between choosing a contract with a successful financier or using the economy-wide screening technology, they must deliver the same expected profits, so that:
\[ \delta_{i,t} = 1 - (\lambda_{i,t})^{\frac{1}{\gamma}}. \]

*If the standard screening technology is close to the frontier screening technology, then the competitive fringe offers a close substitute.*

### 4.2 Financial Innovation

As with entrepreneurial innovation, the probability that the capable financier innovates during period \( t - 1 \) and identifies the entrepreneur capable of innovation \( \mu_{i,t}^f \), depends positively on the amount of resources during period:

\[
N_{i,t-1}^f = (\theta_f \mu_{i,t}^f)^\gamma A_t, \quad \gamma > 1, \tag{16}
\]

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:

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

Solving

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

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

### 4.3 Aggregating the Financial System

To examine the efficiency of a country’s financial system, we aggregate the behavior of financiers across individual sectors to focus on the average, or representative, probability that a financier successfully identifies the capable entrepreneur,

\[ \lambda_t = \int_0^1 \lambda_{i,t} di, \]

Thus, from equation (7), the average level of financial efficiency evolves according to:

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

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):

(20) \( \lambda^* = \frac{\mu^{f*}}{g + \mu^{f*}} \).

so:

(21) \( \frac{\partial \lambda^*}{\partial \mu^{f*}} > 0 \).

Substituting yields:

(22) \( \mu^{f*} = \left( \frac{\beta^{\mu^{e*}} \varphi(1-(\lambda^*)^{\frac{\gamma}{\varphi}})}{g^{\theta_{f}^{\gamma}}} \right)^{\frac{1}{\gamma-1}} \).

And:

**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:**

   \( \frac{\partial \mu^{f*}}{\partial \mu^{f*}} > 0 \).

2. **Financial innovation is a decreasing function of the costs of financial innovation, \( \theta_f \):**

   \( \frac{\partial \mu^{f*}}{\partial \theta_f} < 0 \).

3. **Financial innovation is an increasing function of the rate at which the world technology frontier, \( g \), advances:**

   \( \frac{\partial \mu^{f*}}{\partial g} > 0 \).
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 financiers identify capable entrepreneurs, 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.

4.4 Aggregate Economic Activity

This section aggregates an economy’s economic activity:

\[ A_t = \int_0^1 A_t(i)di, \]

where aggregation is performed across the intermediate sectors.

To derive the law of motion, note that in equilibrium, the expected rate of entrepreneurial and financial innovation is the same across sectors, i.e. \( \mu_{i,t}^f = \mu_{i}^f \) and \( \mu_{i,t}^e = \mu_{i}^e \).

Then, one can simply use the branches of Figure 1 (and equation 13)

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

A country’s average technological productivity in period \( t + 1 \) is a weighted average of sectors which 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 financially
innovate, but nevertheless correctly identified the capable entrepreneur, who in turn successfully innovated.

4.5 Equilibrium Economic Performance Across Countries

Denote a country’s inverse distance from the world technological frontier as \( a_t = A_t / \bar{A}_t \). Each economy takes the evolution of the frontier as given (see below how this is derived). Thus, the technology gap evolves according to:

\[
(26) \quad a_{t+1} = \left( \mu_{t+1}^f \mu_{t+1}^e + (1 - \mu_{t+1}^f) \lambda_{t+1}^{1/(\gamma-1)} \mu_{t+1}^e \right) + \left( 1 - \lambda_{t+1}^{1/(\gamma-1)} - \mu_{t+1}^e \mu_{t+1}^f \right) \frac{1}{1+g} \mu_{t+1}^e \right) a_t \equiv H(a_t).
\]

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

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

where \( \mu^* = \mu_f^* \mu^e + (1 - \mu_f^*) (\lambda^*)^{1/(\gamma-1)} \mu^e \).

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.

\[
(27) \quad g = \mu_1^f \mu_1^e + (1 - \mu_1^f) (\lambda_1^*)^{1/(\gamma-1)} \mu_1^e.
\]

**Proposition 1** An economy’s steady state technology gap:

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.,**
   \[
   \frac{\partial a_{ss}}{\partial \mu^e} \frac{\partial \mu^e}{\partial \theta} < 0, \quad \frac{\partial a_{ss}}{\partial \mu^e} \frac{\partial \mu^e}{\partial \theta_\mu} > 0.
   \]
**Corollary 1** An economy blocking financial innovation will eventually stagnate irrespective of the initial level of screening technology, $\lambda_t$.

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

## 5 Financial Innovation and Convergence: Cross-Country Evidence

AHM cross-country regression framework:

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

Our cross-country regression framework:

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

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 vs. 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 (??) 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 (??), 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 through 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 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 capital 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

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\( b_5 = 0 \) and \( b_6 < 0 \) are robust to using alternative measures of financial development.

Finally, Table 6 considers alternative measures of financial innovation. 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.

Overall, the regression results confirm the theory’s prediction: economies without financial innovation stagnate, irrespective of the initial level of financial development. Put differently, a faster rate of financial innovation accelerates the rate at which an economy converges to the growth rate of the technological leader.

6 Concluding Remarks

Historically, financial innovation has been a ubiquitous characteristic of expanding economies. Whether it is the development of new financial instruments, the creation of new corporate
structures, the formation of new financial institutions, or the development of new accounting and 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.

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 arise to screen potential entrepreneurs. Moreover, financiers engage in the costly and risky process of inventing better processes for screening entrepreneurs. Successful financial innovators are more effective at screening entrepreneurs than other financiers. 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 historical experiences and 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


