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 growth model where entrepreneurs earn profits by inventing better goods and financiers arise to screen entrepreneurs. A novel feature of the model 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. Consequently, technological innovation and economic growth stop unless financiers continually innovate. The model also allows for rent-seeking financial innovation, in which financiers engage in privately profitable but socially inefficient innovation that slows growth. Empirical evidence is more consistent with this dynamic, synergistic model of financial and technological innovation than with existing theories.

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1 Introduction

Financial innovation has been an integral component of economic activity 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 increased specialization, innovation, and economic development (Goetzmann, 2009). In ancient Rome, private investors steadily developed all of the features of limited liability companies, including freely traded shares, an active stock exchange, and corporations that owned property and wrote contracts independently of the individual shareholders. The creation of these corporations eased the mobilization of capital for innovative, large-scale mining technologies (Malmendier, 2009). To finance the construction of vast railroad systems in the 19th and 20th centuries, financial entrepreneurs developed highly specialized investment banks, new financial instruments, and improved accounting systems to foster screening by distant investors (Baskin and Miranti, 1997; and Neal, 1990). Over the last couple of centuries, financiers continuously modified and enhanced securities to mitigate agency concerns and informational asymmetries impeding the financing of frontier technologies (Graham and Dodd, 1934; Allen and Gale, 1994; and Tufano, 2003). More recently, financial entrepreneurs created venture capital firms to screen high-tech inventions and then modified these arrangements to support biotechnology endeavors (Schweitzer, 2006).

Yet, models of economic growth generally ignore financial innovation and instead take the financial system as given and inert. Most frequently, financial arrangements are added to the core models of endogenous technological change developed by Romer (1986, 1990) and Aghion and Howitt (1991). For example, in King and Levine (1993) and Galetovic (1996), 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 Aghion, Howitt, and Mayer-Foulkes (2005), henceforth denoted as AHM, differences in financial development determine the resources available to entrepreneurs for innovation. In Bencivenga and Smith (1991), Levine (1991), and Obstfeld (1994), 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 financial innovation. In Greenwood and Jovanovic's (1990) influential paper, 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 and benefit from financial intermediation, which enhances the efficiency of capital allocation and accelerates 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, financial innovation remains exogenously given.

In this paper, we model both technological and financial innovation as reflecting the explicitly, profit maximizing choices of individuals and explore the implications for economic growth. We start with a textbook model of Schumpeterian growth, where entrepreneurs seek to extract monopoly profits by engaging in the costly and risky process of inventing new goods and production methods (Aghion and Howitt, 2009). Financiers arise to screen potential innovators and identify the most promising ones.

A novel and defining feature of our model is that financial entrepreneurs also innovate to extract monopoly profits. Financiers can engage in a costly and risky innovative activity that, if successful, allows them to screen entrepreneurs better than competing financiers. Successful financial innovation, therefore, generates monopoly rents for the financier, just as successful technological innovation generates monopoly rents for the technological entrepreneur. Since individuals are willing to pay for information about entrepreneurs, financiers arise to provide this information as in Boyd and Prescott (1986). Moreover, we endogenize the actions of financiers. Financiers maximize profits by seeking to create better screening technologies than their competitors, spurring financial innovation and fostering the efficient allocation of capital to technological entrepreneurs striving to innovate.

A second noteworthy feature of the model is that every existing screening methodology becomes less effective at identifying promising entrepreneurs as technology advances. For example, the processes for screening the builders of new, cross-Atlantic ships in the 16^{th} century were less effective at screening innovations in railroad technologies in the 19^{th} century. The methods for screening pharmaceuticals in the 1960s are less appropriate for evaluating biotechnology firms today. At the same time, technological innovation increases the potential profits from financial innovation. Thus, technological innovation makes existing screening technologies obsolete and enhances the returns to inventing improved screening methods. For example, the potential profits from enhanced screening drove financiers to develop specialized investment banks, new contracts, and more elaborate reporting standards to screen railroads and to create venture capital firms to better evaluate and monitor new high-tech firms. Financial and technological innovations are inextricably linked.

Two central, interrelated implications of the theory are that (1) technological change 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 improvements in the screening methodology boost the expected profits from technological innovations. At the extreme, in the absence of financial innovation, existing screening methods will become increasingly obsolete as technological innovation continues, so that the probability of identifying successful entrepreneurs falls toward zero, eliminating growth. Profit seeking financiers, however, can avoid economic stagnation by creating new, more effective screening technologies. The drive for profits by financial and technological entrepreneurs alike, therefore, can produce a continuing stream of financial and technological innovations that sustain long-run growth.

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 AHM: our theory predicts that financial innovation affects the speed with which economies converge to the economic leader's growth path, while their model focuses on the impact of the level of financial development on economic growth. Based on cross-country evidence, AHM find that the level of financial development expedites convergence to the economic leader's long-run growth path. Thus, to evaluate the predictions of our model, we extend the AHM regression framework to also include measures of financial innovation.

We primarily measure financial innovation in a country by how quickly the country adopts a particular innovation associated with screening entrepreneurs. Specifically, we measure the year in which private agents in an economy create a private 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. To further evaluate the theoretical model, we examine the emergence of public credit registries that organize the sharing of information on potential borrowers. According to the model, it is private, profit maximizing financial innovators that invest in screening, so we assess whether public registries provide similar, growth-enhancing services. And, in robustness tests, we use several alternative measures of financial innovation.

Consistent with the empirical prediction of our model, we find that financial innovation boosts the speed with which economies converge to the growth path of the economic leader, but the level of financial development does not. Furthermore, we that the more rapid creation of private credit bureaus boosts the rate of economic convergence, but the more rapid 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. Consistent with theory, the results indicate that financial innovation boosts growth by enhancing the efficiency of resource allocation, not simply by boosting capital accumulation. Overall, the regression results confirm the theory's prediction: economies without financial innovation stagnate, irrespective of the initial level of financial development.

From a policy perspective, the paper stresses adaptability and innovation as key elements for sustaining economic growth. Growth eventually stops in the absence of financial innovation. Legal, regulatory, or policy impediments to financial innovation stymie technological change and economic growth in the long-run. Rather than stressing policies that support a particular level of financial development, the theory highlights the value of policies that facilitate efficient improvements in screening technologies (Merton, 1995).

Furthermore, our paper contributes to debates on the costs and benefits of financial innovation provoked by the recent financial crisis. Many argue that recent financial innovations facilitated the extraction of short-run profits for financiers, not improvements in screening methodologies that enhance social welfare. For example, Dell'Ariccia, Igan, and Laeven (2008), Mian and Sufi (2009), and Keys et al. (2010) show that securitization, one of the key financial innovations in recent years, reduced lending standards and increased loan delinquency rates, while simultaneously boosting the supply of loans and financier profits (Loutskina and Strahan, 2009). Financial innovation can be harmful or inefficient (Gennaioli, Shleifer, and Vishny, 2011; Thakor, 2011). We do not conduct a comprehensive assessment of the pros and cons of financial innovation and financial regulation. Rather, we develop a new theoretical framework in which profit maximizing financiers play a central role in the process of endogenous growth and provide empirical evidence consistent with the model's predictions.

Our model also examines rent-seeking financial innovations. These are innovations that are privately profitable for financiers but socially unproductive. In the model, rent-seeking financial innovation slows growth. In the empirical analyses, however, we do not have a measure of rent seeking; we simply have a measure of financial innovation that fostered information sharing. In the future, this framework can be extended to include policy and other distortions that create incentives for financial innovations that increase financier profits at the expense of social welfare. From this perspective, our paper represents an initial step toward building a more general, dynamic theory of endogenous growth, financial innovation, and financial regulation.

One limitation of our analysis is that we define finance narrowly. We examine only the role of the financial system in screening innovative activities. We do not model risk diversification, pooling, and trading. We do not examine the role of the financial system in reducing transaction costs, enhancing the governance of firms, or in mitigating the moral hazard and adverse selection problems arising from informational asymmetries. Rather, we focus on one critical and core function of a financial system–acquiring and processing information about investments before they are funded.

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 the primary sources of capital for railroads during the initial decades of this new technology (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). For example, after successfully financing the highly profitable line from Manchester to Liverpool, the same British investors played leading roles in screening, funding, and monitoring rail lines in other parts of England (Baskin and Miranti, 1997, p. 137). 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).[1]

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.

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.

But, the venture capital modality did not work well for biotechnology. Venture capitalists could not effectively screen biotech firms because of the scientific breadth of biotechnologies, which frequently require inputs from biologists, chemists, geneticists, engineers, bioroboticists, as well as experts on the myriad of laws, regulations, and commercial barriers associated with

[1] 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.

successfully bringing new medical products to market. It was infeasible to house all of this expertise in banks or venture capital firms. Again, a new technology–biotechnology–offered the possibility of enormous profits, difficulties with screening biotech entrepreneurs and ideas hindered investment in this technology.

So, to earn profits, financiers innovated. They formed new financial partnerships with the one kind of organization with the breadth of skills to screen bio-tech firms: large pharmaceutical companies. Pharmaceutical companies employ, or are in regular contact with, a large assortment of scientists and engineers, have close connections with those delivering medical products to customers, and employ lawyers well versed in drug regulations. Thus, pharmaceutical companies can help identify which bio-tech ideas have the highest probability of yielding profitable products; pharmaceutical companies help bio-tech entrepreneurs determine whether they have a truly promising innovation. Furthermore, given their expertise, investment by a pharmaceutical in a bio-tech firm tends to encourage others to invest in the firm as well. While financial innovation is not the only cause of technological change, the adaptation of finance to technological innovation greased the wheels of technological inventiveness underlying economic growth. Put differently, without financial innovation, improvements in diagnostic and surgical procedures, prosthetic devices, parasite-resistant crops, and other innovations linked to bio-technology would be occurring at a far slower pace.

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

We begin with the discrete-time Schumpeterian growth model developed by AHM. 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.

3.1 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:

$$Z_t = N^{1-\alpha} \int_0^1 A_{i,t}^{1-\alpha} x_{i,t}^{\alpha} di; \qquad \alpha \in (0, 1), \tag{1}$$

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:

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

3.2 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 for 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, financiers arise to screen entrepreneurial ideas; that is, financiers arise to engage in the costly, risky, and potentially profitable process of identifying which entrepreneur is capable of innovating. Then, based on the screening assessments of financiers, households fund the entrepreneur designated as capable.[2]

[2] The assumption that entrepreneurs do not know whether their entrepreneurial idea is profitable is (1) important and (2) well documented. 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 in section 2, along

Let $\mu^e_{i,t}$ 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:

$$A_{i,t} = \left\{ \begin{array}{cc} \bar{A}_t & \text{with probability } \mu^e_{i,t} \\ A_{i,t-1} & \text{with probability } 1-\mu^e_{i,t} \end{array} \right\}, \tag{3}$$

where $\bar{A}_t$ is the world technology frontier. Following AHM, Aghion and Howitt (2009), and several multi-country models of endogenous growth, 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, but which we derive formally below.

A successful innovator enjoys a production cost advantage over entrepreneurs who do not innovate. A successful innovator can produce intermediate goods at the rate of one unit 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 χ 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 χ 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 (χ) 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 (χ) and unsuccessful innovators earn zero profits. Thus, in all intermediate goods sectors, the price, p_{it}, equals χ.

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.[3] Using the demand function for intermediate goods from equation (2), the quantity demanded

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.

[3] 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.

for intermediate good i equals:

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

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

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

3.3 Financiers

Financiers screen entrepreneurs to find the capable one. In return for 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. Thus, financiers screen and households fund entrepreneurial innovation. In the absence of financiers that screen entrepreneurial ideas, innovative activity ceases because households are unwilling to provide resources to a non-screened entrepreneur since the probability of the project being successful is of measure zero. For the same reason, households do not invest in entrepreneurs that financiers designate as incapable of innovating.

For each intermediate good sector i, there is one person born each period $t-1$ who is capable of a successful financial innovation that improves the screening technology next period. A successful financial innovation in sector i allows the respective financier to identify the capable entrepreneur in sector i with probability one. In the absence of successful financial innovation, there is a positive probability that financiers designate the wrong entrepreneur as capable and the economy invests in the wrong 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:

$$m_{i,t} = \left\{ \begin{array}{cc} \bar{A}_t & \text{with probability } \mu_{i,t}^{f} \\ m_{t-1} & \text{with probability } 1-\mu_{i,t}^{f} \end{array} \right\} . \tag{6}$$

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 successful financial innovator in a sector has a clear advantage over other financiers. The successful financial innovator identifies the capable entrepreneur with probability one and is the monopolist provider of the frontier screening technology, $\bar{A}_t$. An unsuccessful financial innovator becomes part of an unlimited number of individuals—a competitive fringe—that 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.

We make the simplifying assumption that everyone in a country in period t has free access to a common, economy-wide screening technology that 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 level; rather, we can simply trace the average distance from the frontier across all sectors in a country. The intuition underlying this simplifying assumption 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, bio-tech innovation in period t will typically involve the use of recent innovations in information technology, chemistry, and other sectors, so that screening bio-tech 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 simplifying assumption, however, is not qualitatively important. For example, 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.[4]

The probability that the financier in sector i correctly identifies the capable entrepreneur, $\lambda_{i,t}$, is a function of the gap between the level of the intermediate sector's frontier technology and the level of the screening technology. If the financier successfully innovates (which occurs with probability $\mu^f_{i,t}$), then there is no gap, so the financier identifies the capable entrepreneur with probability one. If the financier does not successfully innovate (which occurs with probability $1 - \mu^f_{i,t}$), then the financial gap in period t reflects the difference between the technological frontier and last period's common, economy-wide screening technology, such that the probability of correctly identifying the capable entrepreneur is less than one. More specifically,

$$\lambda_{i,t} = m_{i,t}/\bar{A}_t = \left\{ \begin{array}{cc} \bar{A}_t/\bar{A}_t = 1 & \text{with probability } \mu^f_{i,t} \\ m_{t-1}/\bar{A}_t = \frac{\lambda_{t-1}}{1+g} & \text{with probability } 1-\mu^f_{i,t} \end{array} \right\}, \tag{7}$$

where, as described above, g is the growth rate of the world technology leader. Note that within a sector, every financier in the competitive fringe has the same screening technology and therefore identifies the same entrepreneur as the capable entrepreneur. Consequently, households finance only one entrepreneur in a sector. Across sectors in which financiers did not successfully innovate, the financiers correctly identify the capable entrepreneur in λ_t sectors, whereas in $1 - \lambda_t$ sectors, these financiers identify—and households finance—an incapable entrepreneur. Formally, the production of screening from the competitive fringe of financiers 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 the financier successfully identifies—and households 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. Though all screened entrepreneurs sign a perfectly enforceable contract regarding this share, only one entrepreneur in a sector is designated as capable by financiers. This designated entrepreneur, therefore, is the only one in the sector that receives capital from households.

[4] Allowing each intermediate sector to maintain its own screening technology over time delivers a cumbersome analysis without changing the model's qualitative predictions.

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. More specifically, the successful, monopolist financier charges a price such that the entrepreneur is indifferent between using the frontier screening technology and using the old screening technology available to the competitive fringe. For simplicity but without loss of generality, we assume that the perfectly competitive fringe can provide the old screening technology at zero cost, so that entrepreneurs using the competitive fringe of financiers keep 100% of the profits.

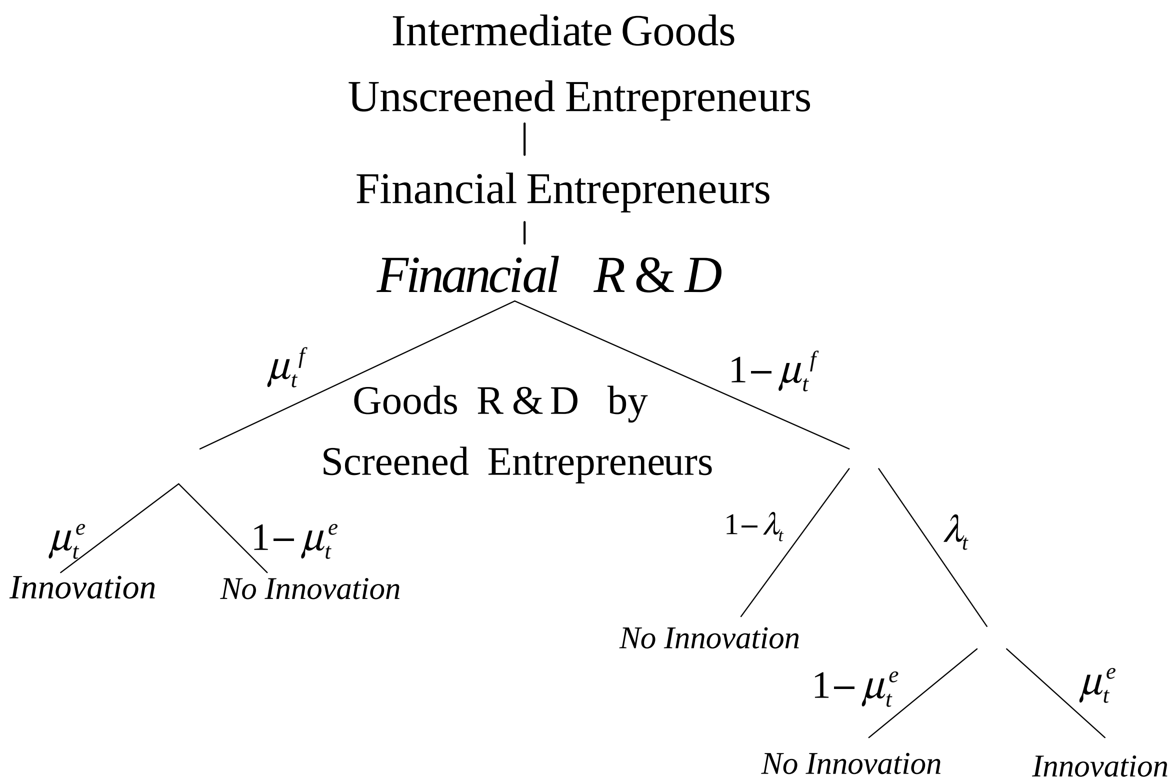
3.4 Timing of Events

At the beginning of period $t-1$ in each sector of each country, the capable financier borrows money from households and invests in financial innovation. If the financier successfully innovates, then this new screening technology identifies the capable entrepreneur with probability one in period t and this financier becomes the monopolist seller of screening services in the sector. There always exists a competitive fringe of financiers that can provide screening services using the old screening technology from period $t-1$. Unscreened entrepreneurs in sector i solicit screening from financiers in sector i. As we show, if a financier innovates, entrepreneurs contract with her. If the capable financier does not innovate, they contract with the competitive fringe. Next, the entrepreneur designated as capable by a financier borrows from households and invests in innovation.

In this paper, profit-maximizing financiers arise to screen entrepreneurs. While previous Schumpeterian growth models, e.g., Aghion and Howitt (2009), assume that the identity of the capable entrepreneur is costlessly available to everyone, we do not. Identifying the capable entrepreneur is a costly, risky, and potentially profitable activity that motivates the emergence of financiers. However, we do not examine the screening of the screeners. So, we assume that the capable financier is common knowledge, which is consistent with core models of financial intermediation, such as Diamond (1984) and Boyd and Prescott (1986), in which the screening of financiers is much less costly than the screening of entrepreneurs.

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.



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 positively on the amount of resources invested in entrepreneurial innovation during period $t-1$, $N_{i,t-1}^e$, so that:

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

As in AHM, 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, θ 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 $N^e_{i,t-1}$ 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 $\Pi^e_{i,t}$, so that:

$$\Pi^e_{i,t} = (1-\delta_{i,t})\left(\beta\mu^e_{i,t}\pi\bar{A}_t - N^e_{i,t-1}\right). \tag{9}$$

Risk-neutral individuals in the first period of life provide resources to entrepreneurs designated as capable by financiers.[5] 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 entrepreneur that is rated as capable by a successful financier is $R^e_{i,t} = \frac{1+r}{\mu^e_{i,t}}$. In turn, households charge the interest rate of $R^e_{i,t} = \frac{1+r}{\lambda_{i,t}\mu^e_{i,t}}$ to entrepreneurs designated as capable by the competitive fringe of financiers that conducted the screening using 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 fully consistent.

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

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

where we assume that $\beta\pi < \gamma\theta^\gamma$ to ensure that the equilibrium probability of successful entrepreneurial innovation is less than one ($\mu^*_{e,t} < 1$) 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 when a financier successfully innovates are intuitively. Entrepreneurs invest more in innovation and boost the probability of success when (1) the net

[5] We 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, as explained by AHM, 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.

profits per unit of the intermediate good, π, are higher and (2) the cost of entrepreneurial innovation, θ, is lower. If π and θ are common across sectors, then $\mu^{e*}_{i,t} = \mu^{e*}\ \forall\ i$.

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

$$\Pi^{e*}_{i,t} = (1 - \delta_{i,t})\mu^{e*}\varphi \bar{A}_t, \tag{11}$$

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

Now, consider entrepreneurs screened by the competitive fringe of financiers 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, $\Pi^{e\prime}_{i,t}$, i.e., the expected profits of an entrepreneur screened using the old screening technology is:

$$\Pi^{e\prime}_{i,t} = \beta\lambda_{i,t}\mu^{e}_{i,t}\pi\bar{A}_t - N^{e}_{t-1}. \tag{12}$$

Consequently, the profit maximizing probability of entrepreneurial innovation for imperfectly screened entrepreneurs, $\mu^{'}_{e,t}$, is:

$$\mu^{e'}_{i,t} = (\lambda_{i,t})^{\frac{1}{\gamma-1}}\ \mu^{e*}. \tag{13}$$

Substituting (13) in (12) one derives the maximal net expected revenue of an entrepreneur selected using the old screening technology as:

$$\Pi^{e'}_{i,t} = (\lambda_{i,t})^{\frac{\gamma}{\gamma-1}}\ \mu^{e*}\varphi\bar{A}_t. \tag{14}$$

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, π, are higher and (2) the cost of entrepreneurial innovation, θ, is lower, i.e.,*

$$\frac{\partial\mu^{e'}_{i,t}}{\partial\pi} > 0, \quad \frac{\partial\mu^{e'}_{i,t}}{\partial\theta} < 0.$$

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

$$\frac{\partial\mu^{e'}_{i,t}}{\partial\lambda_{i,t}} > 0.$$

Proof. These properties follow by directly differentiating equation (13). □

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 successful financier or using the economy-wide screening technology supplied by the competitive fringe, these two alternatives must deliver the same expected profits. Formally, (11) must equal (14), so that:

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

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 the competitive fringe offers a close substitute. On the other hand, if the available screening technology is a poor substitute for a successful financier's newly developed screening capabilities, then the financier can obtain a larger fraction of expected entrepreneurial profits.

4.2 Financial Innovation

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

$$N^f_{i,t-1} = (\theta_f \mu^f_{i,t})^{\gamma} \bar{A}_t, \quad \gamma > 1, \tag{16}$$

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, $\mu^f_{i,t}$, as the technological frontier advances since the entrepreneurs that are screened by financiers are striving to reach the world technology frontier.

The financier chooses $N^f_{i,t-1}$ to maximize expected profits, $\Pi^f_{i,t}$. Since a successfully innovating financier keeps the fraction $\delta_{i,t}$ of expected entrepreneurial profits, $\Pi^{e*}_{i,t}$, the financier's expected profits equals:

$$\Pi^f_{i,t} = \mu^f_{i,t} \beta \delta_{i,t} \Pi^{e*}_{i,t} - N^f_{i,t-1}. \tag{17}$$

The financier maximizes profits by borrowing $N^f_{i,t-1}$ 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 $R_t^f = \frac{1+r}{\mu_{t,i}^f \mu_{t,i}^e}$, 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:

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

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,

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

where $\lambda_{i,t}$ equals the probability that the financier in sector i correctly identifies the entrepreneur capable of innovating in sector i during period t. From equation (7), the average level of financial efficiency evolves according to the following equation:

$$\lambda_t = \mu_t^f + (1 - \mu_t^f) \frac{\lambda_{t-1}}{1+g} . \tag{19}$$

The financial sector identifies the capable entrepreneur with probability one in the fraction μ_t^f of the sectors in which the financier successfully innovated last period. Since we aggregate financial screening across a continuum of sectors, we ignore negligible relative size differences. In the remaining $1 - \mu_t^f$ of the sectors, the financial sector identifies 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 λ^* in equation (19):

$$\lambda^* = \frac{\mu^{f*}}{g + \mu^{f*}} . \tag{20}$$

Directly differentiating equation (20) reveals an important comparative static of this economy:

$$\frac{\partial \lambda^*}{\partial \mu^{f*}} > 0. \tag{21}$$

The higher is the steady state rate of financial innovation, μ^{f*}, the more efficient is the economy's financial system at identifying capable entrepreneurs in the steady state, λ^*.

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

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

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

$$F(\mu^{e*}, \mu^{f*}, \theta_f) \equiv 0, \tag{23}$$

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, θ_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 μ_t^{f*} with respect to entrepreneurial innovation μ^{e*} in order to highlight the nexus between entrepreneurial and financial innovation. Of course, it is trivial to show that since μ^{e*} itself is a function of exogenous features of the economy

(θ, π), (part 1 of Lemma 1), changes in these structural parameters will affect the equilibrium financial innovation.

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. Thus, countries in which it is more expensive to innovate financially (higher θ_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). More on this in the empirical section of the paper.

4.4 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. $\mu_{i,t}^f = \mu_t^f$ and $\mu_{i,t}^e = \mu_t^e$. Then, one can simply use the branches of Figure 1 and equation (13) to derive the law of motion of average productivity:

$$A_{t+1} = (\mu_{t+1}^f \mu_{t+1}^e + (1-\mu_{t+1}^f)\lambda_{t+1}^{1/(\gamma-1)}\mu_{t+1}^e)\bar{A}_{t+1} + (1-\lambda_{t+1}^{1/(\gamma-1)}\mu_{t+1}^e - \mu_{t+1}^f\mu_{t+1}^e + \mu_{t+1}^f\lambda_{t+1}^{1/(\gamma-1)}\mu_{t+1}^e)A_t. \tag{24}$$

Inspecting (24) reveals that a country's average technological productivity in period $t+1$ is a weighted average of sectors which implement the frontier technology, $\bar{A}_{t+1}$, and of sectors using the average technology of period t, A_t. The weights are functions of (a) the rate of financial innovation, μ^f_{t+1}, (b) the quality of the financial screening technology, λ_{t+1}, and (c) the probability of successful entrepreneurial innovation, μ^e_{t+1}. In particular, the productivity parameter will equal $\bar{A}_{t+1}$ 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.

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 $w_t = (1-\alpha)Z_t = (1-\alpha)\zeta A_t$.[6] In terms of profits, successful entrepreneurs earn $\pi\overline{A}_t$, where $\pi = (\chi - 1)\left(\frac{\alpha}{\chi}\right)^{\frac{1}{1-\alpha}}$. Thus, per capita gross domestic product is the sum of added value across sectors:

$$Y_t = w_t + \mu_t \pi_t = (1-\alpha)\zeta A_t + \mu_t \pi \overline{A}_t \ , \tag{25}$$

where μ_t is the fraction of goods' sectors with successful entrepreneurial innovation in period t.

The following section characterizes the growth rate of Y_t as a function of the underlying entrepreneurial and financial structure of the economy.

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:

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

[6] Unlike AHM 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 available to those in sectors where financiers did not successfully innovate. 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 the proceeds, households are willing to lend any amount at the prevailing interest rates.

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

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

where $\mu^* = \mu^{f*}\mu^{e*}+(1-\mu^{f*})\left(\lambda^*\right)^{1/(\gamma-1)}\mu^{e*}$ is the fraction of entrepreneurially innovating 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,

$$g = \mu_1^{f*}\mu_1^{e*} + (1-\mu_1^{f*})\left(\lambda_1^*\right)^{1/(\gamma-1)}\mu_1^{e*} \ . \tag{27}$$

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

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

1. *An economy blocking financial innovation will eventually stagnate* irrespective *of the initial level of screening technology, λ_t.*

$$a_{ss} = 0 \ \textit{if} \ \mu^{f*} = 0.$$

2. *The steady state technology gap is increasing at the rate of financial innovation, μ^{f*}, i.e.,*

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

3. *The steady state technology gap is increasing at the rate of entrepreneurial innovation, μ^{e*}, i.e.,*

$$\frac{\partial a_{ss}}{\partial \mu^{e*}} > 0.$$

Proof. The first property is obtained through direct substitution of $\mu^{f*} = 0$ in a_{ss}. The remaining two properties are derived by differentiating a_{ss} with respect to the relevant arguments.□

It is straightforward to derive the ultimate determinants of the steady state technological gap, a_{ss}, in terms of the exogenous parameters using the results established in part 1 of Lemma 1 and parts 1 and 2 of Lemma 2. The next section briefly discusses the derived properties.

[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.

4.6 Dynamic versus Static Financial Markets

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

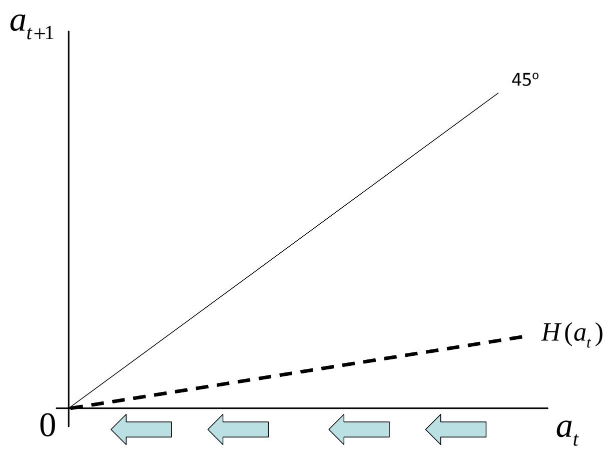


Figure 2a: Static Financial Markets

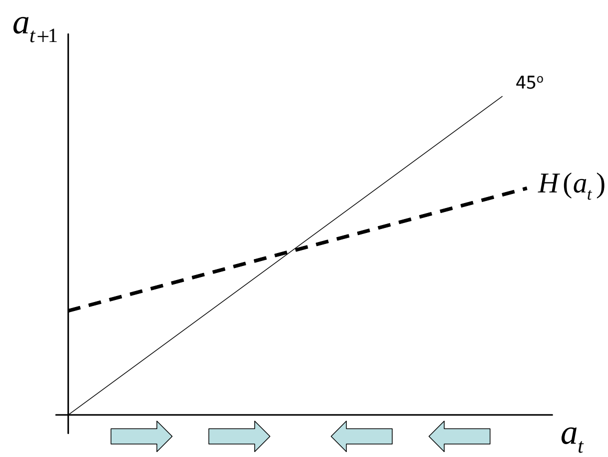


Figure 2b: Dynamic Financial Markets

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. $\mu^{f*} > 0$, 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 $H(a_t)$ curve upwards in Figure 2b, increasing a country's steady state level of technology relative to the frontier, a_{ss}. In a similar fashion, factors affecting entrepreneurial innovation also shape a country's steady state technology gap.

4.7 Rent-seeking Financial Innovation

So far, financiers generate profits only by innovating and creating a superior screening methodology. Financiers provide privately profitable and socially beneficial services.

In practice, however, financiers can engage in activities that are privately profitable but socially inefficient, which we call rent-seeking activities. For example, a financier could expend resources seeking to limit competition, either through private means or by lobbying regulators to implement protective policies. This would allow the rent-seeking financier to extract monopolist rents by providing the freely available screening methodology from last period. And, the rent-seeking financier would obtain these rents without having to engage in the comparatively costly process of trying to innovate to develop an improved screening methodology. Such rent-seeking activity does not improve screening and therefore does not foster economic growth. Indeed, recent research by Keys et al (2010) stresses that one recent financial innovation, securitization, did not improve screening.

In this subsection, we highlight the importance of the incentive structure that financiers face as they choose between investing in financial innovation that can improve screening or in rent-seeking activities that do not improve screening but that can yield monopolistic rents. For simplicity, we model rent seeking as the capable financier investing in activities that increase the production costs of the competitive fringe of financiers. Thus, a successful rent-seeking investment means the financier can provide the freely available screening methodology from last period at a lower cost than competitors and therefore charge a monopoly price for this screening methodology, reflecting impediments to competition.

Thus, we assume that the capable financier faces a two-stage maximization problem. In the first stage, she decides how much to invest in financial innovation to improve screening. In the second stage, if financial innovation is unsuccessful, she decides how much to invest in rent seeking. This problem is solved by backwards induction, i.e. first by analyzing the behavior of the financial entrepreneur in case of unsuccessful financial innovation.

Formally, let b_t be the fraction of the entrepreneurial profits that a rent-seeking financier obtains from entrepreneurs using the common, economy-wide screening methodology. Investment in rent seeking, B_t, is an increasing function of b_t, and is proportional to the technological frontier preserving the symmetry with the innovation costs, that is:

$$B_t = (\theta_b b_t)^{\gamma} \bar{A}_t, \quad \gamma > 1, \tag{28}$$

where θ_b measures the institutional costs of rent seeking, so that a large θ_b implies that it is more difficult for a rent-seeking financier to limit competition and extract monopoly rents by employing the commonly available screening methodology. Consequently, expected profits under rent seeking, $R(b_t)$, are given by:[8]

$$R(b_t) = \beta b_t \Pi_t^{e'} - B_t. \tag{29}$$

The fraction of entrepreneurial profits obtained by the rent-seeking financier, b_t, that maximizes (29) subject to (28) is equal to:

$$b_t^* = \left(\frac{\beta \lambda_t^{\gamma/(\gamma-1)} \mu^{e*} \phi}{\theta_b \gamma} \right)^{1/(\gamma-1)}, \tag{30}$$

which obtains its steady state value, b^* when $\lambda_t = \lambda^*$.

The comparative statics are intuitive. A higher level of the standard screening technology, λ_t, induces financiers to increase their rent-seeking efforts because the improvements in screening—and hence the potential profits—from pushing the screening methodology to the world frontier are small. This finding suggests that when a country's financial system is close to the screening frontier, this increases rent-seeking incentives. As we show below, increases in rent seeking slow financial innovation and economic growth. At the same time, in economies where institutions impose a higher cost on rent seeking, θ_b, financiers allocate fewer resources towards rent seeking and, as we will now show, invest comparatively more in improving screening.

Replacing (30) in (29) we may derive the expression for the maximal rent-seeking profits, $X(b_t^*)$, described by:

$$X(b_t^*) = \bar{A}_t (b_t^*)^{\gamma} (\gamma - 1). \tag{31}$$

Having analyzed the behavior of the potential financier in case of unsuccessful innovation, we now investigate the profit maximizing rate of financial innovation in the presence of rent-seeking opportunities. The key difference compared to the financiers' expected profits described

[8] The potential financier borrows from households to finance the rent seeking activity. Note that the only risk associated with rent seeking is the probability that the imperfectly screened entrepreneur is unsuccessful.

by (17) is that now the outside option of a potential financier is no longer zero profits but the possibility of investing in rent seeking and impeding the use of the standard screening methodology by the competitive fringe.

Hence, the expected profit function is modified to reflect this:

$$\Pi_t^f\Big|_{rentseeking} = \beta\mu_t^f\delta_t\Pi_t^{e*} - N_{t-1}^f + (1-\mu_t^f)X(b_t^*). \tag{32}$$

Expected profits are maximized subject to (16), (15) and (31). Replacing λ_t with its equilibrium value λ^*, we obtain the following equilibrium rate of financial innovation:

$$\mu^{f*}\Big|_{rentseeking} = \left(\frac{\beta\mu^{e*}\varphi(1-(\lambda^*)^{\frac{\gamma}{\gamma-1}}) - \beta(b^*)^\gamma(\gamma-1)}{\gamma\theta_f^\gamma}\right)^{\frac{1}{\gamma-1}}. \tag{33}$$

The following Lemma summarizes the properties of equilibrium financial innovation.

Lemma 3 *The properties of financial innovation in the steady state when rent seeking is possible,* $\mu_t^f\Big|_{rentseeking}$*, are as follows:*

1. *Financial innovation under rent seeking is strictly lower than financial innovation without rent seeking:*
$$\mu^{f*}\Big|_{rentseeking} < \mu^{f*}.$$
2. *Financial innovation increases as the cost of rent seeking increases,* θ_b*:*
$$\frac{\partial\mu_t^{f*}}{\partial\theta_b} > 0.$$

Proof. The first property follows by directly comparing (22) to (33). The second one obtains by differentiating (33) with respect to θ_b $\square$

This Lemma has direct implications for the rates of financial and technological innovation. In countries where it is comparatively attractive for financiers to engage in rent seeking—that is, in countries where financiers can more easily become the monopolistic providers of commonly available screening methodologies, financiers invest less in financial innovation. This reduces the rate of improvement in screening methodologies and slows the rate of technological innovation.

This analysis of rent-seeking financiers within a model of Schumpeterian growth and financial innovation offers both policy implications and guidance for evaluating the model's predictions empirically. First, political, legal, and regulatory institutions that discourage rent seeking and promote competition will tend to foster socially beneficial financial innovations that facilitate technological progress. In turn, institutions and policies that restrict competition in finance and provide a high return to rent-seeking investments by financiers will tend to retard financial and technological innovation.

Second, the analysis provides guidance both on how to measure financial innovation and on how *not* to measure financial innovation. In terms of what *not* to measure, computing the investment expenditures or profits of financiers might reflect rent-seeking activities or other factors, not genuine financial innovations that improve screening technologies. Rather, it is important to measure an actual improvement in a screening methodology and gauge how quickly different countries innovate to transfer the new screening technology to their country. Such a direct measure of the adaptation and adoption of a new screening technologies would directly capture the mechanics of the model.

5 Financial Innovation and Convergence: Cross-Country 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 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:

$$g - g_1 = b_0 + b_1 F + b_2(y - y_1) + b_3 F(y - y_1) + b_4 X + u, \tag{34}$$

where $g - g_1$ is average growth rate of per capita income relative to U.S. growth over the period 1960-95, F is financial development in 1960, which is measured as credit to the private sector as a share of GDP, $y - y_1$ is log of per capita income relative to U.S. per capita income, X is set of control variables, and u 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 b_1 is not significantly different from zero and that b_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:

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

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 than 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 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. Such bureaus allow banks to obtain credit information on customers of other banks and serve as an important screening mechanism for new borrowers. 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., Jaffee and Russel, 1976, and 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 test the *differential* impact of private credit bureaus and public credit registries on economic growth using data.

As an 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 includes 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 (following Rajan and Zingales, 1998).

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 (34) 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 (35), 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 also reported in 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 $(y - y1)$ 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 $f(y - y1)$ 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 $(g - g1)$ 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 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 noninterest 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 though 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 our theory, we test 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, py. 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 lack of education (or because financial innovation matters for growth only because it facilitates investment in education, as in Galor and Zeira, 1993). 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 nonbank 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. 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, which generate 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. Institutions, laws, regulations, and policies that impede financial innovation slow technological change and economic growth.

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Table 1. Summary Statistics

This table presents summary statistics of our main regression variables. g - g1 is the growth rate of real per capita GDP of the country minus the U.S. growth rate in real per capita GDP, both are computed over the period 1960-95. F is financial development, measured as private credit to GDP in 1960. y-y1 is log of per capita income relative to U.S. per capita income. f is screening innovation, measured as the fraction of years a private bureau, from Djankov, (2007), existed within the period 1960-95. School is average years of schooling in the population over 25 in 1960. Gov is government size, measured as government expenditure as a share of GDP, averaged over 1960-1995. pi is inflation rate, measured as the log difference of consumer price index average from 1960-1995. Bpm is the black market premium, computed as the ratio of the black market exchange rate and the official exchange rate minus one. Trade is openness to trade, measured as the sum of real exports and imports as a share of real GDP, averaged over 1960-1995. Revc is number of revolutions and coups, averaged over 1960-1990. A revolution is defined as any illegal or forced change in the top of the governmental elite, any attempt at such a change, or any successful or unsuccessful armed rebellion whose aim is independence from central government. Coup d'Etat is defined as an extra-constitutional or forced change in the top of the governmental elite and/or its effective control of the nation's power structure in a given year. Unsuccessful coups are not counted. Assass is number of political assassinations per 1000 inhabitants, averaged over 1960-1990. Avelf is ethnic diversity, measured as the average value of five indices of ethnolinguistic fractionalization, with values ranging from 0 to 1, where higher values denote higher levels of fractionalization.

Variable	Obs	Mean	Std. Dev.	Min	Max
g-g1	56	0.2841	1.6975	-4.5242	4.9406
F	56	24.3997	20.9498	1.6661	115.3919
y-y1	56	-1.3717	0.8017	-3.0074	0.0000
F*(y-y1)	56	-23.2496	16.7918	-75.6332	0.0000
f	51	0.3843	0.3925	0.0000	1.0000
f*(y-y1)	51	-0.3773	0.5295	-2.0051	0.0000
school	56	4.3146	2.4868	0.5400	10.0700
gov	56	14.5572	5.0223	6.6813	30.6264
pi	56	16.5671	19.1244	3.6289	90.7832
bmp	56	26.5132	52.8158	0.0000	277.4202
trade	56	59.6028	38.4645	14.0502	231.6857
revc	56	0.1590	0.2332	0.0000	0.9704
assass	56	0.3107	0.5206	0.0000	2.4667
avelf	56	0.2539	0.2448	0.0025	0.8723

Table 2. Financial Development, Financial Innovation, and Growth

This table presents ordinary least squares (OLS) and instrumental variable (IV) estimates of a regression model that extends the AHM model of financial development and growth to include screening innovation. The dependent variable is the growth rate of real per capita GDP of the country minus the US growth rate in real per capita GDP, g - g1. Both are computed over the period 1960-95. F is financial development, measured as private credit to GDP in 1960, and f is screening innovation, measured as the fraction of years a private bureau, from Djankov, (2007), existed within the period 1960-95. We include the same control variables as AHM. The regression in Column (1) is estimated using OLS and replicates the AHM results, limiting the sample to those countries with data on private credit to GDP in 1960. The regression in Column (2) is estimated using OLS and adds screening innovation. The instrumental variables in regression (3) are legal origin and the change in the Abiad and Mody (2005) financial reform index over the period 1973-1995. We are missing data on financial reform index for 9 countries. The instrumental variable in regression (4) is the legal origin of the country. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

VARIABLES	(1) g-g1	(2) g-g1	(3) g-g1	(4) g-g1
(y-y1)	-0.472	0.100	0.351	-0.0893
	(0.529)	(0.711)	(0.557)	(0.502)
F	-0.00498	0.00221	-0.0187	
	(0.00737)	(0.00812)	(0.0119)	
F*(y-y1)	-0.0299**	-0.0268*	-0.0336	
	(0.0134)	(0.0135)	(0.0248)	
f		-0.900	1.074	0.317
		(0.829)	(1.320)	(0.942)
f*(y-y1)		-1.698*	-1.880***	-2.485***
		(0.945)	(0.670)	(0.546)
School	0.200*	0.0960	-0.0897	-0.0435
	(0.112)	(0.142)	(0.141)	(0.131)
Gov	0.0132	0.0337	0.0471	0.0370
	(0.0410)	(0.0362)	(0.0298)	(0.0364)
Pi	-0.000608	-0.0139	-0.0338***	-0.0293***
	(0.0142)	(0.0139)	(0.0109)	(0.0104)
Bpm	-0.0170***	-0.0105**	-0.0100***	-0.00945***
	(0.00540)	(0.00485)	(0.00299)	(0.00300)
Trade	0.0149**	0.00518	-0.00719	-0.00327
	(0.00580)	(0.00889)	(0.00804)	(0.00848)
Revc	-1.435	-0.525	0.286	-0.285
	(0.959)	(1.007)	(0.844)	(0.907)
Assass	-0.00700	-0.137	-0.650*	-0.338
	(0.285)	(0.374)	(0.370)	(0.359)
Avelf	-0.0644	0.582	1.530	1.298*
	(0.986)	(1.050)	(1.000)	(0.769)
Constant	-2.172*	-1.368	0.120	-0.486
	(1.183)	(1.798)	(1.392)	(1.254)
1st-stage F-test: F (p-value)	--	--	0.10	--
1^{st}-stage F-test: F*(y-y1) (p-value)	--	--	0.09	--
1st-stage F-test: f	--	--	0.06	0.03
1^{st}-stage F-test: f*(y-y1)	--	--	0.00	0.01
Sargan J-test (p-value)	--	--	0.95	0.23
Observations	56	51	47	51
R-squared	0.558	0.585	0.409	0.242

Table 3. Financial Development, Financial Innovation, and Productivity Growth

This table presents ordinary least squares (OLS) and instrumental variable (IV) estimates of a regression model that extends the AHM model of financial development and growth to include screening innovation. The dependent variable is average growth rate of multifactor productivity of the country relative to the US, pg - pg1, computed over the period 1960-95. Productivity data are from Benhabib and Spiegel (2005). py - py1 is the log of productivity in 1960 relative to the United States. F is financial development, measured as private credit to GDP in 1960, and f is screening innovation, measured as the fraction of years a private bureau, from Djankov, (2007), existed within the period 1960-95. We include the same control variables as AHM. The regression in Column (1) is estimated using OLS and limits the sample to those countries with data on private credit to GDP in 1960. The instrumental variables in regression (2) are legal origin and the change in the Abiad and Mody (2005) financial reform index over the period 1973-1995. We are missing data on financial reform index for 9 countries. The instrumental variable in regression (3) is the legal origin of the country. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

	(1)	(2)	(3)
VARIABLES	pg - pg1	pg - pg1	pg - pg1
py - py1	-0.629	0.174	-0.421
	(0.558)	(0.502)	(0.394)
F	0.00604	-0.0112	
	(0.00634)	(0.00793)	
F*(py - py1)	-0.0172	-0.0464**	
	(0.0140)	(0.0227)	
f	-0.608	0.498	-0.120
	(0.567)	(1.363)	(0.765)
f*(py - py1)	-1.900*	-2.140*	-2.540***
	(1.020)	(1.170)	(0.537)
School	0.0971	0.0144	0.0127
	(0.0750)	(0.0888)	(0.0575)
Gov	0.0166	0.0182	0.0196
	(0.0197)	(0.0184)	(0.0180)
Pi	-0.00501	-0.0194***	-0.0169***
	(0.00545)	(0.00650)	(0.00605)
Bmp	-0.00120	-0.000129	-0.000936
	(0.00224)	(0.00172)	(0.00174)
Trade	0.00143	-0.00260	-0.00282
	(0.00549)	(0.00499)	(0.00464)
Revc	-0.794*	-0.0855	-0.419
	(0.466)	(0.537)	(0.479)
Assass	0.194	-0.104	0.0421
	(0.167)	(0.219)	(0.184)
Avelf	0.164	0.862*	0.380
	(0.576)	(0.504)	(0.447)
Constant	-1.760**	-0.939	-0.797
	(0.731)	(0.739)	(0.650)
1st-stage F-test: F (p-value)	--	0.00	--
1^{st}-stage F-test: F*(y - y1) (p-value)	--	0.04	--
1st-stage F-test: f	--	0.34	0.16
1^{st}-stage F-test: f*(y - y1)	--	0.00	0.00
Sargan J-test (p-value)	--	0.54	0.34
Observations	48	46	48
R-squared	0.592	0.441	0.336

Table 4. Financial Development, Financial Innovation, and Growth: Other Interactions

This table presents instrumental variable (IV) estimates of a regression model that extends the AHM model of financial development and growth to include screening innovation. The dependent variable is the growth rate of real per capita GDP of the country minus the US growth rate in real per capita GDP, g - g1. Both are computed over the period 1960-95. F is financial development, measured as private credit to GDP in 1960, and f is screening innovation, measured as the fraction of years a private bureau, from Djankov, (2007), existed within the period 1960-95. We include the same control variables as AHM but also include interactions between these control variables, and y – y1, the log of per capita GDP in 1960 relative to the United States. The interacted control variables, X, are denoted in each column header. The instrumental variables for F and S are legal origin dummy variables and the change in the Abiad and Mody (2005) financial reform index over the period 1973-1995. We are missing data on financial reform index for 9 countries. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

VARIABLES	(1) X=school	(2) X=gov	(3) X=pi	(4) X=bmp	(5) X=trade	(6) X=revc	(7) X=assass	(8) X=avelf
y-y1	0.117	-0.356	0.351	0.542	0.457	0.309	-0.0115	-0.214
	(0.587)	(0.864)	(0.617)	(0.571)	(0.614)	(0.576)	(0.575)	(0.588)
F	-0.0175	-0.0293	-0.0192	-0.0167	-0.0174	-0.0172	-0.0105	-0.0110
	(0.0123)	(0.0220)	(0.0147)	(0.0111)	(0.0117)	(0.0144)	(0.0105)	(0.00833)
F*(y-y1)	-0.0511	-0.0356	-0.0321	-0.0286	-0.0347	-0.0324	-0.0309	-0.0237
	(0.0328)	(0.0317)	(0.0246)	(0.0207)	(0.0244)	(0.0216)	(0.0216)	(0.0189)
f	0.684	1.852	1.071	0.831	1.062	0.922	0.665	0.00744
	(1.225)	(2.070)	(1.514)	(1.317)	(1.293)	(1.508)	(1.142)	(0.828)
f*(y-y1)	-2.544***	-1.850**	-1.823**	-2.081***	-1.853***	-1.928***	-1.953***	-1.979***
	(0.821)	(0.790)	(0.771)	(0.629)	(0.675)	(0.729)	(0.578)	(0.674)
School	0.0616	-0.235	-0.0850	-0.159	-0.0791	-0.0807	-0.0343	-0.0654
	(0.181)	(0.201)	(0.139)	(0.145)	(0.139)	(0.147)	(0.117)	(0.0971)
Gov	0.0319	0.127*	0.0449	0.0447	0.0460	0.0455	0.0398	0.0610**
	(0.0328)	(0.0720)	(0.0292)	(0.0304)	(0.0300)	(0.0300)	(0.0270)	(0.0283)
Pi	-0.0275**	-0.0372***	-0.0392	-0.0213*	-0.0325***	-0.0337***	-0.0343***	-0.0305***
	(0.0121)	(0.0133)	(0.0304)	(0.0127)	(0.0114)	(0.0107)	(0.00953)	(0.00877)
Bmp	-0.0128***	-0.0126***	-0.0105***	-0.0719**	-0.0104***	-0.0101***	-0.0103***	-0.00913***
	(0.00375)	(0.00339)	(0.00291)	(0.0339)	(0.00311)	(0.00287)	(0.00278)	(0.00300)
Trade	-0.00137	-0.00757	-0.00691	-0.00420	-0.0100	-0.00688	-0.00551	-0.00746
	(0.00891)	(0.00908)	(0.00783)	(0.00794)	(0.0111)	(0.00783)	(0.00745)	(0.00581)
Revc	1.021	0.485	0.189	0.661	0.249	0.495	0.270	-0.190
	(1.174)	(1.006)	(0.841)	(0.936)	(0.822)	(2.541)	(0.773)	(0.715)
Assass	-0.835**	-0.865*	-0.622	-0.600	-0.641*	-0.672*	0.349	-0.596*
	(0.420)	(0.495)	(0.427)	(0.367)	(0.363)	(0.398)	(0.822)	(0.309)
Avelf	1.901	2.031	1.463	0.975	1.564	1.539	1.365	3.593**
	(1.215)	(1.349)	(0.955)	(0.898)	(1.003)	(0.936)	(0.916)	(1.725)
X*(y-y1)	0.204	0.0761	-0.00458	-0.0257*	-0.00286	0.125	0.649	1.473*
	(0.187)	(0.0665)	(0.0197)	(0.0139)	(0.00722)	(1.329)	(0.473)	(0.827)
Constant	-0.870	-0.0475	0.204	0.705	0.107	0.0707	-0.547	-0.385
	(1.650)	(1.785)	(1.365)	(1.231)	(1.311)	(1.364)	(1.146)	(1.389)
Sargan J-test (p-value)	0.95	0.87	0.93	0.88	0.96	0.95	0.90	0.13
Observations	47	47	47	47	47	47	47	47
R-squared	0.330	0.216	0.421	0.456	0.422	0.429	0.492	0.573

Table 5. Financial Development, Financial Innovation, and Growth: Other Proxies for Financial Development

This table presents instrumental variable (IV) estimates of a regression model that extends the AHM model of financial development and growth to include screening innovation. The dependent variable is the growth rate of real per capita GDP of the country minus the US growth rate in real per capita GDP, g - g1. Both are computed over the period 1960-95. We limit the sample to those countries with data on private credit to GDP in 1960. In regression (1), F is measured as the ratio of liquid liabilities to GDP in 1960. In regression (2), F is measured as the ratio of bank assets to GDP in 1960. In regression (3), F is measured as the index of creditor rights from LLSV (1998). In regression (4), F is measured as the index of accounting quality in 1983 from LLSV (1998). f is screening innovation, measured as the fraction of years a private bureau, from Djankov, (2007), existed within the period 1960-95. We include the same control variables as AHM. The instrumental variables for F and S are legal origin dummy variables and the change in the Abiad and Mody (2005) financial reform index over the period 1973-1995. We are missing data on financial reform index for 9 countries. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

VARIABLES	(1) F=liquid liabilities	(2) F=bank assets	(3) F=creditor	(4) F=accounting
y-y1	1.123	0.549	-0.347	3.284
	(0.801)	(0.596)	(0.477)	(3.258)
F	-0.0109	-0.0160	-0.286	-0.0679
	(0.0159)	(0.0127)	(0.554)	(0.0479)
F*(y-y1)	-0.0386**	-0.0406	-0.298	-0.0738
	(0.0193)	(0.0276)	(0.286)	(0.0530)
f	-0.245	0.527	-0.588	0.110
	(1.412)	(1.518)	(0.716)	(0.898)
f*(y-y1)	-2.900***	-2.156***	-2.508***	-1.266*
	(0.998)	(0.747)	(0.537)	(0.656)
school	-0.0528	-0.0733	-0.0738	0.0694
	(0.114)	(0.137)	(0.0911)	(0.105)
gov	0.0277	0.0411	0.0242	0.0571*
	(0.0322)	(0.0279)	(0.0355)	(0.0306)
pi	-0.0296***	-0.0301**	-0.0299**	-0.00498
	(0.00897)	(0.0131)	(0.0118)	(0.0158)
bmp	-0.00892***	-0.0114***	-0.0268*	-0.0558*
	(0.00302)	(0.00296)	(0.0147)	(0.0286)
trade	-0.00384	-0.00689	-0.00369	-0.00688
	(0.00708)	(0.00712)	(0.00726)	(0.00793)
revc	1.136	0.535	1.911**	0.0342
	(1.223)	(0.850)	(0.961)	(1.620)
assass	-0.605	-0.708*	-0.699	-0.364
	(0.400)	(0.395)	(0.457)	(0.435)
avelf	0.864	1.637*	-0.724	-0.369
	(0.744)	(0.993)	(0.889)	(1.659)
Constant	0.409	0.126	0.678	3.047
	(1.104)	(1.261)	(1.331)	(3.273)
Sargan J-test (p-value)	0.94	0.96	0.36	0.78
Observations	45	47	38	33
R-squared	0.425	0.438	0.682	0.620

Table 6. Financial Development, Financial Innovation, and Growth: Other Proxies for Financial Innovation

This table presents instrumental variable (IV) estimates of a regression model that extends the AHM model of financial development and growth to include screening innovation. The dependent variable is the growth rate of real per capita GDP of the country minus the US growth rate in real per capita GDP, g - g1. Both are computed over the period 1960-95. F is the ratio of private credit to GDP in 1960. We limit the sample to those countries with data on private credit to GDP in 1960. f denotes screening innovation. In regression (1), f is measured as the fraction of years a private credit bureau existed within the period 1960-95. In regression (2), f is measured as the fraction of years a public credit registry existed within the period 1960-95. In regression (3), f is measured as the growth in the ratio of private credit to GDP over the period 1960-95. We include the same control variables as AHM. The instrumental variables for F and S are legal origin dummy variables and the change in the Abiad and Mody (2005) financial reform index over the period 1973-1995. We are missing data on financial reform index for 9 countries. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

VARIABLES	(1) f=fraction of years private bureau	(2) f=fraction of years public registry	(3) f=growth in private credit to GDP
y-y1	0.351	-0.235	0.233
	(0.557)	(0.707)	(0.598)
F	-0.0187	-0.00823	0.00259
	(0.0119)	(0.0112)	(0.00849)
F*(y-y1)	-0.0336	-0.0462	-0.0165
	(0.0248)	(0.0287)	(0.0202)
f	1.074	2.581	0.0365
	(1.320)	(1.925)	(0.167)
f*(y-y1)	-1.880***	4.284	-0.310***
	(0.670)	(3.033)	(0.105)
school	-0.0897	0.0945	-0.00734
	(0.141)	(0.138)	(0.114)
gov	0.0471	0.0168	0.00994
	(0.0298)	(0.0373)	(0.0310)
pi	-0.0338***	0.0146	-0.000276
	(0.0109)	(0.0111)	(0.00897)
bmp	-0.0100***	-0.0154***	0.00365
	(0.00299)	(0.00474)	(0.00439)
trade	-0.00719	0.00782	-0.00607
	(0.00804)	(0.00855)	(0.00691)
revc	0.286	-1.499*	-3.487**
	(0.844)	(0.902)	(1.570)
assass	-0.650*	-0.254	0.287
	(0.370)	(0.415)	(0.521)
avelf	1.530	0.656	-2.378**
	(1.000)	(1.778)	(0.951)
Constant	0.120	-1.474	0.291
	(1.392)	(1.601)	(1.650)
Sargan J-test (p-value)	0.95	0.38	0.26
Observations	47	47	47
R-squared	0.409	0.175	0.371