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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 endogenous growth model where entrepreneurs earn monopoly 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 existing screening process, however, becomes less effective as technology advances. Consequently, technological innovation and, thus, economic growth stop unless financiers continually innovate. Historical observations and empirical evidence are more consistent with this dynamic model of financial innovation and endogenous growth than with existing models of financial development and growth.

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

JEL classification Numbers: G0; O31; O4

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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 do not emerge and 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 (1990), financial intermediaries produce information about investment projects and thereby improve capital allocation. Since there is a fixed cost to joining financial intermediaries, growth means that more individuals can afford to join 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 ultimately exogenous, so that the rate of financial innovation is not determined by the choices of profit maximizing agents.

In this paper, we model both technological and financial innovation as reflecting the profit maximizing decisions 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 maximize 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. Unlike Boyd and Prescott (1986), coalitions of agents - financial institutions - do not emerge to screen and monitor entrepreneurs. Rather, individuals are willing to pay for information about entrepreneurs, so financiers arise to provide this information. Moreover, we endogenize the actions of financiers. Financiers maximize profits by seeking to create better screening technologies than their competitors.

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.

Though the major 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 present three types of evidence that advertise the value of this dynamic model of financial innovation and endogenous growth. First, the model predicts that technological innovation should be positively correlated with financial innovation. We assess this prediction by examining whether labor productivity growth in the financial sector is correlated with that of other industries from 1967 to 2000 in the United States. The correlation coefficient between productivity growth in the financial and manufacturing sectors is almost one (0.99), suggesting a powerful link between technological and financial innovation.

Second, cross-country growth comparisons further emphasize the central role of financial innovation in economic growth. AHM show that the level of financial development, as measured by the ratio of private credit to Gross Domestic Product (GDP) shape whether a country converges to the technological leader. Our theory suggests that it is the rate of financial innovation that determines the likelihood of a country converging to the growth rate of the frontier economy. This is what we find. Using the growth rate of the ratio of private credit to GDP as an empirical proxy for financial innovation, the evidence is consistent with the view that financial innovation is crucial for economic growth. While the growth rate of private credit to GDP is an unsatisfactory measure of improvements in screening technology, this additional piece of evidence underscores the value of incorporating financial innovation into our models of entrepreneurship and growth.

Third, as emphasized above and developed further below, history exemplifies the importance of financial innovation for igniting and sustaining economic growth. For example, Harris (1994; 1997; 2000) stresses that legal impediments to financial innovation, especially limits on the creation of limited liability corporations, temporarily slowed technological invention and economic growth in England and France during the 18th and 19th centuries. In particular, restrictions on the use of limited liability impeded firms from growing to efficient sizes and shareholders from diversifying their investment across several firms while receiving a reliable flow of information about those firms. Similarly, Kuran (2006) links the comparative underdevelopment of the Islamic world with stagnant financial arrangements. Although the financial rules of Islam were efficient for a few centuries, they were not adaptable enough to permit the creation of new financial arrangements, such as the limited liability corporation, to mobilize, pool, and administer the funds of thousands of investors. According to Kuran (2006), the Islamic system stymied financial innovation and therefore severely hindered technological innovation and growth. As another example, recent research shows that when regulators removed impediments to competition in the U.S. banking system, this stimulated the development and spread of new financial technologies for screening firms, with positive ramifications on entrepreneurship and economic growth (Hubbard and Palia, 1995; Jayaratne and Strahan, 1996; Black and Strahan, 2002; Kerr and Nanda, 2009; and Beck, Levine, and Levkov, 2010). In the paper, we discuss the series of financial innovations that spurred the development of railroads, as well as other examples from financial history, to further stress the indispensable role of financial innovation in supporting continuous improvements in technology.

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. We do not conduct an assessment of the pros and cons of financial innovation. 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. 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 financial function – acquiring and processing information about investments before they are funded.

The remainder of the paper is organized as follows. Section 2 outlines the basic structure of the model, and Section 3 solves the model, determines the factors underlying steady state growth, and derives testable implications. Section 4 provides additional historical examples and suggestive empirical evidence. Section 5 concludes.

2 The Basic Structure of the Model

We begin with the Schumpeterian growth model developed by AHM. Economic activity extends over infinite discrete time. There are k countries that do not exchange goods or factors, but do make use of each others' technological ideas. There is a continuum of individuals in each country whose fixed population 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 of life and none in the second period. The utility function is linear in consumption, so that $U = c_1 + \beta c_2$, where c_1 is consumption in the first period of life, c_2 is consumption in the second period of life, and $\beta \in (0, 1)$ is the rate at which individuals discount the utility of consumption in period 2 relative to that in period 1.

2.1 Final Output

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

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

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

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

2.2 Intermediate Goods

In each intermediate goods sector i, a continuum of individuals with an entrepreneurial idea is born in period $t-1$. Only one entrepreneurial idea per sector has a positive probability of producing a successful innovation and improving the production technology in period t. The quality of each entrepreneurial idea is unknown to the entrepreneur and households looking to invest in entrepreneurial ideas. As we discuss below, financiers arise to screen entrepreneurial ideas and identify the entrepreneur that is capable of innovating.

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

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

where $\bar{A}_t$ is the world technology frontier. The world technology frontier grows at a constant rate g, which is taken as exogenous for now, but which we derive formally below.

If the capable entrepreneur successfully innovates, she 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 $\chi > 1$. Thus, successful innovators enjoy a production cost advantage over entrepreneurs who do not innovate. 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.

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. 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. Using the demand function for intermediate goods from equation (2), the quantity demanded for intermediate good i equals

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

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

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

2.3 Financiers

Financiers screen individuals with entrepreneurial ideas and assess which entrepreneur is capable of innovating. In return for their screening services, financiers are paid a share of entrepreneurial profits which we describe formally below. Financiers provide their assessments of entrepreneurial ideas to households, who use this information to make investment decisions. In the absence of profit maximizing financiers that screen entrepreneurial ideas, innovative activity ceases because households are unwilling to provide resources to an unscreened 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.

A financier can earn monopoly rents by successfully inventing a better screening technology than competitor financiers. In period $t-1$, a single financier has a positive probability of successfully innovating and improving the screening technology in each intermediate sector i. 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.

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

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

We index the level of the potential frontier of the screening technology by the aggregate level of the world technology frontier, $\bar{A}_t$. As the technological frontier advances, the frontier screening technology also advances, though the actual screening technology, $m_{i,t}$, may lag behind the frontier screening technology, $\bar{A}_t$. If financial innovation is successful, the financier becomes the monopolist producer of the frontier screening technology, $\bar{A}_t$, in her sector and identifies the capable entrepreneur with probability one. As with entrepreneurial innovation, if financial innovation is unsuccessful in sector i, then an unlimited number of individuals – a competitive fringe – can screen entrepreneurial ideas in sector i during period $t-1$ using the economy-wide screening technology of period $t-1$, m_{t-1}, which equals the average of the screening technologies across all sectors in period $t-1$. This common, economy-wide screening technology across non-financially innovating sectors is a simplifying assumption, which derives from the observation that entrepreneurs in each sector aim at implementing the world technology frontier, $\bar{A}_t$, which encompasses ideas and technologies across all sectors. Thus, innovative activity in, for example, biotechnology in period t will likely involve the use of recent innovations in information technology, chemistry, and other sectors, so that screening potential innovations in biotechnology requires the ability to screen technologies from these other sectors as well. Rather than define the common, economy-wide screening technology across non-financial innovating sectors as the average of last period's screening technologies, we could choose any point in the distribution of sector screening technologies from last period without loss of generality. For example, if we were to choose the maximum screening technology across all sectors from last period and use this as the common screening technology for non-financially innovating sectors, we obtain the same qualitative predictions. [1]

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

[1] Furthermore, allowing each intermediate sector to maintain its own screening technology over time would deliver a cumbersome analysis without changing the qualitative predictions of the model.

and the level of the screening technology. If the financier successfully innovates, then there is no gap. If the financier does not successfully innovate, then the financial gap reflects the difference between the technological frontier and last period's economy wide screening technology, so that:

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

Consequently, a successful financier – a financier that successfully innovates in sector i in period $t-1$ – will choose the entrepreneur capable of delivering a technological innovation in period t with probability one. In a sector where the financier does not innovate in period $t-1$, the probability of correctly identifying the potential entrepreneur is less than one, equaling the ratio of the economy's screening capacity as of period $t-1$, m_{t-1}, relative to the technological frontier of period t.

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 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 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 is designated as capable and receives external financing. 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.

2.4 Timing of Events

At the beginning of each period $t-1$ in each sector, unscreened entrepreneurs solicit screening from the financier with the potential to innovate. The financier both borrows money from households and invests in financial innovation. If the financier fails to innovate, the competitive fringe of financiers use the existing screening technology as of period $t-1$ to identify and designate one entrepreneur as capable. If the financier successfully innovates, then this new screening technology identifies the capable entrepreneur with probability one. Next, the entrepreneur designed as capable borrows from households and invests in innovation.

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

Figure 1 below summarizes all possible scenarios.

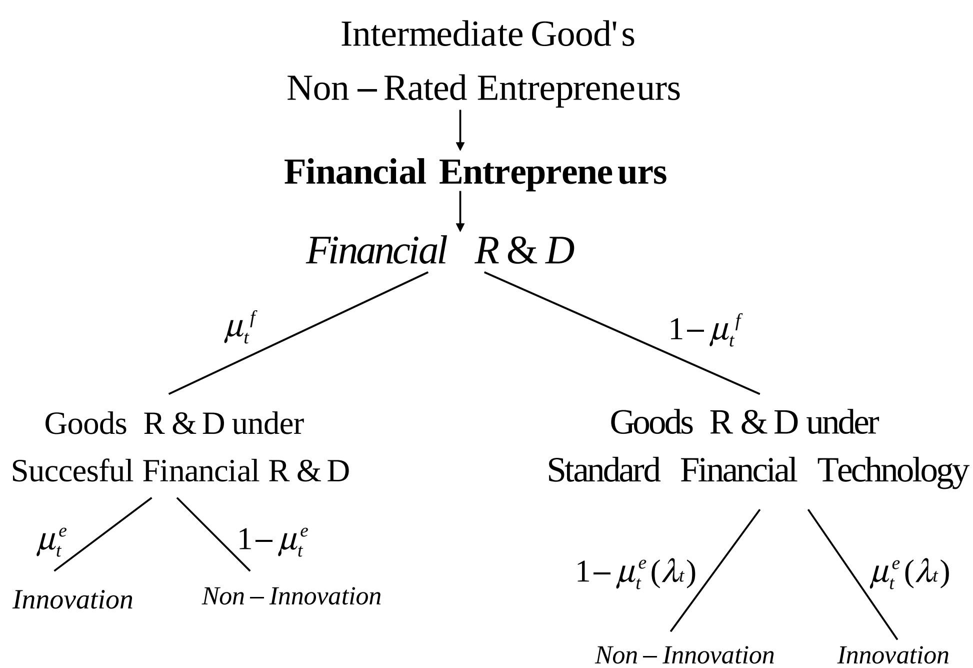

Figure 1: Timing of Events

3 Innovation and Aggregate Growth

3.1 Entrepreneurial Innovation

The probability that a capable entrepreneur successfully innovates in period t, $\mu^e_{i,t}$, depends positively on the quantity of final goods invested in entrepreneurial innovation during period $t-1$, $N^e_{i,t-1}$, so that

$$N^e_{i,t-1} = (\theta\mu^e_{i,t})^\gamma \bar{A}_t, \quad \gamma > 1.$$

As in AHM, the cost of 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 $\mu^e_{i,t}$ as the technology frontier advances.

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

$$\Pi^e_{i,t} = (1-\delta_{i,t})\left(\beta\mu^e_{i,t}\pi\bar{A}_t - N^e_{i,t-1}\right). \tag{8}$$

Risk neutral individuals in the first period of life provide resources to entrepreneurs designated as capable by financiers. They provide unlimited 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.

First, consider entrepreneurs that are screened by successful financiers, so that the entrepreneur designated as capable knows with probability one that she is the capable entrepreneur. She then chooses to borrow and invest in innovation, such that the profit maximizing probability of successfully innovating is:

$$\mu^{e*}_{i,t} = \left(\frac{\beta\pi}{\gamma\theta^\gamma}\right)^{1/(\gamma-1)}, \tag{9}$$

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 (9), the comparative statics with perfect screening are intuitively appealing. Entrepreneurs invest more in innovation and boost the probability of success when (1) the net 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 (9) into (8) yields the net expected profits of an entrepreneur screened by a successful financier,

$$\Pi^{e*}_{i,t} = (1-\delta_{i,t})\mu^{e*}\varphi\bar{A}_t, \tag{10}$$

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

Second, 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

$$\Pi^{e\prime}_{i,t} = \beta\lambda_{i,t}\mu^{e}_{i,t}\pi\bar{A}_t - N^{e}_{t-1}. \tag{11}$$

Consequently, the profit maximizing probability of entrepreneurial innovation for imperfectly screened entrepreneurs, $\mu^{\prime}_{e,t}$, is

$$\mu^{e^{\prime}}_{i,t} = (\lambda_{i,t})^{\frac{1}{\gamma-1}}\,\mu^{e*}. \tag{12}$$

Substituting (12) in (11) one derives the maximal net expected revenue of an entrepreneur selected using the old screening technology as

$$\Pi^{e^{\prime}}_{i,t} = (\lambda_{i,t})^{\frac{\gamma}{\gamma-1}}\,\mu^{e*}\varphi\bar{A}_t. \tag{13}$$

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.,

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

2. *Entrepreneurial innovation is an increasing function of the standard financial efficiency, $\lambda_{i,t}$ i.e.,*

$$\frac{\partial \mu_{i,t}^{e'}}{\partial \lambda_{i,t}} > 0$$

Proof. These properties follow by directly differentiating equation (12) □

We can now derive the fraction of entrepreneurial profits accruing to the entrepreneur $(1-\delta_{i,t})$ and financier $(\delta_{i,t})$. For the unrated 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, (10) must equal (13), so that

$$\delta_{i,t} = 1 - (\lambda_{i,t})^{\frac{\gamma}{\gamma-1}} \, . \tag{14}$$

Equation (14) 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.

3.2 Financial Innovation

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

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

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

The financier chooses $N^f_{i,t-1}$ 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

$$\Pi^f_{i,t} = \mu^f_{i,t}\beta\delta_{i,t}\Pi^{e*}_{i,t} - N^f_{i,t-1}. \tag{15}$$

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 final goods output to financiers seeking to innovate at an interest rate of $R^f_t = \frac{1+r}{\mu^f_{t,i}\mu^e_{t,i}}$, 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 (14) into (15), the financier chooses to borrow and invest in financial innovation such that profit maximizing probability of successful financial innovation in sector i during period t is

$$\mu^{f*}_{i,t} = \left(\frac{\beta\mu^{e*}_t\varphi(1-(\lambda_{i,t})^{\frac{\gamma}{\gamma-1}})}{\gamma\theta^\gamma_f}\right)^{\frac{1}{\gamma-1}}, \tag{16}$$

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

3.3 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 capable entrepreneur in sector i during period t. From equation (7), the average level of financial efficiency evolves according to the following equation:

$$\lambda_t = \mu^f_t + (1-\mu^f_t)\frac{\lambda_{t-1}}{1+g} \tag{17}$$

The financial sector identifies the capable entrepreneur with probability one in the fraction μ^f_t of the sectors in which the financier successfully innovated last period. Since we aggregate financial efficiency 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 efficiency, let $\lambda_t = \lambda_{t-1} = \lambda^*$ and $\mu_t^f = \mu^{f*}$ in the steady state and then solve for λ^* from equation (17):

$$\lambda^* = \frac{\mu^{f*}}{g + \mu^{f*}}. \tag{18}$$

Directly differentiating equation (18) reveals an important comparative static of this economy:

$$\frac{\partial \lambda^*}{\partial \mu^{f*}} > 0. \tag{19}$$

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 (16), so that

$$\mu^{f*} = \left(\frac{\beta \mu^{e*} \varphi (1 - (\lambda^*)^{\frac{\gamma}{\gamma-1}})}{\gamma \theta_f^{\gamma}} \right)^{\frac{1}{\gamma-1}}. \tag{20}$$

Finally combining (18) and (20), yields the implicit function

$$F(\mu^{e*}, \mu^{f*}, \theta_f) \equiv 0, \tag{21}$$

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 (20) according to the Implicit Function Theorem delivers the results. □

The properties of financial innovation in equilibrium highlight the nexus between entrepreneurial and 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 growth. In particular, the cost of financial innovation θ_f affects the rate of financial and hence technological innovation. Thus, countries in which it is more expensive to innovate financially (higher θ_f) will tend to grow slower than economies with less expensive barriers to financial innovation. 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 Beck, Demirguc-Kunt, and Levine (2003, 2005), Gennaioli and Shleifer (2007), and Levine (2005a, 2005b).

3.4 Aggregate Economic Activity

This section aggregates an economy's economic activity and examines its components. We define the economy's average level of technological productivity, A_t, as:

$$A_t = \int_0^1 A_t(i)di,$$

where aggregation is performed across the continuum of intermediate sectors.

To derive the law of motion of the average level of technological productivity, note that in equilibrium, the expected rate of entrepreneurial and financial innovation is the same across sectors, i.e. $\mu_{i,t}^f = \mu_t^f$ and $\mu_{i,t}^e = \mu_t^e$. Then, simply use the branches of Figure 1 and equation (12) to derive the law of motion of average productivity:

$$A_{t+1} = (\mu_{t+1}^f \mu_{t+1}^e + (1-\mu_{t+1}^f)\lambda_{t+1}^{1/(\gamma-1)}\mu_{t+1}^e)\bar{A}_{t+1} + (1-\lambda_{t+1}^{1/(\gamma-1)}\mu_{t+1}^e - \mu_{t+1}^f\mu_{t+1}^e + \mu_{t+1}^f\lambda_{t+1}^{1/(\gamma-1)}\mu_{t+1}^e)A_t. \tag{22}$$

Inspecting (22) 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_{t+1}^f, (b) the quality of the financial screening technology, λ_{t+1}, and (c) the probability of successful entrepreneurial innovation, μ_{t+1}^e. 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 where financiers 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 $w_t = (1-\alpha)Z_t = (1-\alpha)\zeta A_t$.[2] 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:

$$Y_t = w_t + \mu_t \pi_t = (1-\alpha)\zeta A_t + \mu_t \pi \overline{A}_t \tag{23}$$

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.

[2] Unlike AHM where the proportionality of the wage rate to the domestic productivity determines the level of technology investment in a credit constrained country, in our setup this ratio plays no role in determining entrepreneurial investment. As shown in equations (9) and (12), the probability of entrepreneurial innovation depends only on entrepreneurial profits and the level of the standard financial screening technology available to those in sectors where financiers did not financially innovate. Domestic productivity just 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.

3.5 Economic Performance Across Countries

Denote a country's 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:

$$a_{t+1} = (\mu^f_{t+1}\mu^e_{t+1} + (1-\mu^f_{t+1})\lambda^{1/(\gamma-1)}_{t+1}\mu^e_{t+1}) + \frac{\left(1 - \lambda^{1/(\gamma-1)}_{t+1}\mu^e_{t+1} - \mu^f_{t+1}\mu^e_{t+1} + \mu^f_{t+1}\lambda^{1/(\gamma-1)}_{t+1}\mu^e_{t+1}\right)}{1+g} a_t \equiv H(a_t) \tag{24}$$

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 it is common in other Schumpeterian models, we suppose that the growth rate of the technological frontier, is determined by the equilibrium rate of entrepreneurial innovations in the leading country labeled 1. That is,

$$g = \mu^{f*}_1\mu^{e*}_1 + (1-\mu^{f*}_1)\left(\lambda^*_1\right)^{1/(\gamma-1)}\mu^{e*}_1 \tag{25}$$

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. *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. *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.□

The next section briefly discusses the derived properties.

3.6 Dynamic versus Static Financial Markets

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

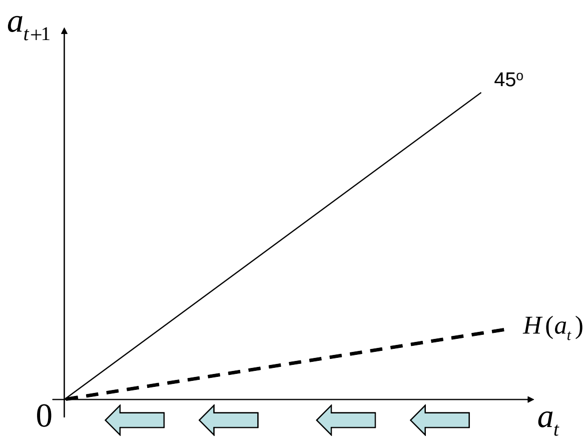

Figure 2a: Static Financial Markets

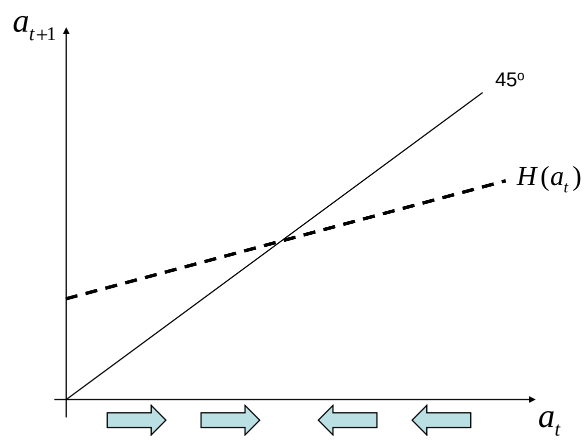

Figure 2b: Dynamic Financial Markets

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. 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 (23), grows at the rate of the world technology frontier.

Among economies that already financially innovate, 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. It is worth stressing that given the interactive feedback effects between financial and entrepreneurial innovation, interventions in either sector will have an amplifying effect on the economy's innovation rate.

4 Evidence

In this section, we present historical observations and empirical evidence regarding the main assumptions and key predictions of the model. While these findings are consistent with the model, they do not represent a formal test, or validation, of the model's predictions. In particular, we are limited by the absence of a generally accepted measure of financial innovation and fully valid instrumental variables for financial innovation. Nonetheless, these initial results advertise the potential usefulness of the model and the value of conducting more rigorous assessments of the link between financial innovation and technological change.

4.1 Historical Examples

We begin by describing a series of financial innovations that facilitated the development of the railroads in the 19th and 20th centuries. While we do not formally test hypotheses regarding the connections between financial and technological innovation in the railroad industry, the history of this central feature of the industrial revolution is fully consistent with this paper's emphasis on the co-evolution of financial and technological innovation.

Initially, the railway system was funded at the local level through private equity financing because of the informational problems associated with screening and monitoring railroads from afar (Baskin and Miranti, 1997, 134-146). Railroads were new, complex, and spanned a large geographic area. Consequently, prominent local investors who could observe and monitor the activities of railroads were virtually the only source of private capital during the early decades of the 19th century (Chandler, 1954, 1965, 1977). This reliance on local finance, however, severely restricted the growth and development of railroads.

Since problems with acquiring and disseminating reliable information about railroads impeded profitable investments, financial entrepreneurs arose to mitigate this problem and thereby spur improvements in railroad technology and expansion throughout England and the United States (Baskin and Miranti, 1997, p. 137-138). Specialized financiers and investment banks with reputations for integrity and competence emerged to both mobilize capital from individuals to invest in railroads and then to oversee those investments by serving on the boards of directors of railroad corporations (Carosso, 1970). In terms of specialized financiers, Baskin and Miranti (1997, p. 137) note that after successfully financing the highly profitable line from Manchester to Liverpool, the same British investors were prominent in funding rail lines in other parts of England. In the United States, the major investment banking houses of J.P. Morgan & Company and Kuhn-Loeb & Company mobilized funds from wealthy investors in the United States and Europe to invest in the construction of railroad lines throughout the United States. This additional capital not only improved transportation through more track mileage, it also financed improvements in the quality of transportation in the form of faster, more comfortable, and safer trains (Chandler, 1977).

Besides the emergence of specialized investment institutions, improvements in managerial accounting methods and financial reporting facilitated the financing, expansion, and improvement of railroads. As documented by Chandler (1965, 1977), the size and complexity of railroads forced them to pioneer new methods for collecting, organizing, and assessing price, usage, breakdown, and repair information. While these new forms of managerial control boosted operational efficiency, they also made it easier for outside investors to assess and monitor railroads. Overtime, financiers were able to assemble and evaluate this information on a monthly, and then on a daily, and by the close of the 19th century on an hourly basis. These improvements in monitoring reduced the barriers to external finance, encouraged investment and innovation, and thereby spurred growth in the railroad industry (Baskin and Miranti, 1997, p. 143-145).

Financial entrepreneurs also developed new financial instruments and greatly expanded the use of existing securities to ease financial constraints on railroads, reduce the risk of bankruptcy from short-term reductions in income, and customize the risks facing potential investors in railroads. Baskin and Miranti (1997, p. 146-157) and Tufano (1997, p. 20-28) describe how these financial instruments were combined to facilitate the flow of capital from diverse investors to railroads. For example, preferred stock holders receive income before common stock holders and are senior to common stock in bankruptcy, but preferred share holders do not have voting rights and unlike debt holders they do not have the right to push a company into bankruptcy. With income bonds, purchasers receive a promised stream of interest payments, but these payments are contingent on the railroad's profitability. This reduces the risk of very costly bankruptcies from short-term reductions in profits. For other investors, railroads used liens, rather than debentures, to attract risk averse investors, while deferred coupon debt and super long maturity bonds allowed railroads to further custom design their securities for investors. By providing a menu of securities with different characteristics, railroads greatly expanded the range of outside investors interested in railroad securities. Financial engineering facilitated the expansion of and improvements in railroads in Britain and the United States.

As a second example, consider the commercial revolution of the Middle Ages. Lopez (1976) and Braudel (1992) stress that increased trade facilitated specialization, which in turn spurred innovative improvements in productive technologies. Furthermore, Goetzmann (2005) stresses that the boom in international trade required improvements in the methodologies for valuing transactions occurring at different times, in different currencies, with different rates of payment, and with a complex variety of weights and measures. Standard financial practices were inadequate to address these new needs.

Indeed, Goetzmann (2005) shows that Leonardo of Pisa, the mathematician best remembered for his "Fibonacci" series and for introducing Italy to the Arabic number system, wrote his magnum opus, *Liber Abaci*, in 1202 primarily to facilitate commerce by developing more precise, practical valuation techniques. *Liber Abaci* was taught throughout Europe, where it was used to train entrepreneurs to overcome common obstacles, and brought Fibonacci considerable recognition and wealth. Over time, Fibonacci's contributions were essential ingredients in the financial revolution that brought liquid securities markets, life insurance, annuities, mutual funds, derivative securities, and deposit banking to Europe. These financial innovations in turn spurred commerce and growth.

As a final example, the 20th century development of venture capital firms to screen and finance high-technology firms and recent modifications to this model to support biotechnology further illustrate the vital role of financial innovation in encouraging technological change. During the second half of the 20th century, new, high-technology firms found it increasingly difficult to obtain financing. Commercial banks were reluctant to lend because there was not yet a secure cash flow to repay the loan. It was difficult to issue securities in public markets because the technology was complex and difficult to evaluate. Furthermore, the ultimate payoffs were highly risky, and many high-technology firms were run by scientists with no experience in operating profitable companies (Gompers and Lerner, 2001).

Venture capital firms arose to screen entrepreneurs and provide technical, managerial, and financial advice to new high-technology firms. Venture capitalists frequently became wealthy through their own successful innovations in high-technology, which provides a basis of expertise for evaluating new entrepreneurs. In terms of funding, venture capitalists hold large, private equity stakes that establish a long-term commitment to the enterprise, while offering the possibility of enormous profits after several years. Furthermore, venture capitalists become active investors, taking seats on the board of directors, providing regular advice, making business contacts, and solving managerial and financial problems. Thus, this new financial arrangement arose to facilitate the financing of frontier technological innovations, especially in information technology.

As the frontiers of biotechnology opened, the venture capitalists needed to modify their model for screening, monitoring, and financing technological innovation. In particular, successfully developing a new biotechnology frequently required the inputs of scientists, engineers, and experts from a wide-variety of disciplines, enormous capital injections for sustained periods, and expertise with drug regulations.

Overtime, venture capitalists adapted their funding structures to facilitate innovation in biotechnology. In particular, they coordinated with large pharmaceuticals to finance and assist biotechnology firms. 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. Making these resources available to biotechnology firms increases the probability of successfully creating a valuable product. Furthermore, large pharmaceuticals help in the screening of biotechnology firms, which makes external investors more confident about participating in the financing of these ventures. Thus, financial entrepreneurs facilitate technological innovators in their quests to make new and better products.

4.2 Financial and Technological Innovation

We next examine a key feature of our model and one that departs from the existing literature on finance and growth: financial innovation is an increasing function of the rate at which entrepreneurs innovate and vice versa. In other words, innovation in the real sector should be positively correlated with innovation in the financial sector.

We assess this hypothesis using data on productivity growth across U.S. industries over time from the U.S. Bureau of Labor Statistics (BLS), which has annual data on labor productivity growth by sector over the period 1967 to 2000. We use this data to contrast labor productivity in the financial sector with that of other sectors in the U.S. economy. Specifically, we test if there is a positive correlation over time between labor productivity growth in the financial sector and that in other sectors.

We compute labor productivity at the sectoral level as output per hour of all employees in the sector. We use the 1987 U.S. SIC industry classification to group industries into the financial sector and manufacturing sectors, limiting the analysis to a comparison of the financial services industry to the manufacturing industry. Specifically, we use SIC code 602, denoting commercial banks, as proxy for the financial sector, and SIC code 20, denoting manufacturing, as proxy for the manufacturing sector.

Using these proxies for the financial sector and real sector, and using annual observations on the percentage growth rate of labor productivity in either sector, we find that the correlation between labor productivity growth in the financial sector and the labor productivity growth in the real sector over the period 1967 to 2000 is high at 45 percent. The results are consistent with the view that innovation in the real sector is strongly positively correlated with innovation in the financial sector.

4.3 Financial Innovation and Endogenous Growth

Finally, we evaluate a second 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 specification to include not only measures of financial development but also financial innovation. In particular, first consider the AHM regression framework:

$$g - g_1 = b_0 + b_1 F + b_2(y - y_1) + b_3 F(y - y_1) + b_4 X + u, \tag{26}$$

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.

Consistent with the model developed in AHM, they 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:

$$g - g_1 = b_0 + b_1 F + b_2(y - y_1) + b_3 F(y - y_1) + b_4 X + b_5 f + b_6 f(y - y_1) + u, \qquad (27)$$

where financial innovation, f, is measured as the average growth rate of financial development over the period 1960-95. Note that f is measured over the sample period, while F is measured at the beginning of the sample period. 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.[3]

For comparison purposes, we test these empirical predictions using the same dataset as in Aghion et al. (2005) (and confirm the results using the more recent version, 6.2, of the Penn World Tables). We start by running a simple cross-sectional OLS regression. The results are presented in the first two columns of Table 1. We indeed find that the interaction between financial innovation (f) and deviation of growth from US growth ($f(y - y_1)$) is negative and significant.

Next, we run two sets of instrumental variables (IV) regressions to address concerns about endogeneity between growth, financial development and financial innovation. In column (3), we use both legal origin dummy variables of the country and the change over the period 1973-1995 in the Abiad and Mody (2005) financial reform index as instruments for financial development and financial innovation. Furthermore, for the interactive terms, $F(y - y1)$ and $f(y - y1)$, we use the interactions of the initial real per capital GDP gap with the United States $(y - y1)$ 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 depressed do not innovate and improve their screening technologies and other financial practices. Thus, for the financial development terms, F and $F(y-y1)$, we use the same instruments as in AHM. We add corresponding instruments for the financial innovation terms, f and $f(y - y1)$, where 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. In column (4), we drop financial development and use the legal origin dummy variables as instruments for financial

[3]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.

innovation (following Beck et al. (2003, 2005) and Gennaioli and Shleifer (2007)), 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. Again, the first-stage regressions reject the null hypothesis that the instruments do not explain f and $f(y - y1)$.The IV results are fully consistent with those from the OLS specification.

In sum, 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.

5 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 supporting economic growth. Institutions, laws, regulations, and policies that impede financial innovation slow technological change and economic growth.

References

[1] Abiad, Abdul, Mody, Ashoka. 2005. "Financial Reform: What Shakes It? What Shapes it?" *American Economic Review* 95, 66-88.

[2] Acemoglu, Daron, Zilibotti, Fabrizio. 1997. "Was Prometheus Unbound by Chance: Risk, Diversification, and Growth." *Journal of Political Economy* 105: 709-775.

[3] Aghion, Philippe, Howitt, Peter. 1992. "A Model of Growth through Creative Destruction." *Econometrica* 60(2): 323-351.

[4] Aghion, Philippe, Howitt, Peter. 2009. *The Economics of Growth*. Cambridge, MA: MIT Press.

[5] Aghion, Philippe, Howitt, Peter, Mayer-Foulkes, David. 2005. "The Effect of Financial Development on Convergence: Theory and Evidence." *Quarterly Journal of Economics* 323-351.

[6] Allen, Franklin, Gale, Douglas. 1994. *Financial Innovation and Risk Sharing*. Cambridge, MA: Cambridge University Press.

[7] Baskin, Jonathan B., Miranti, Paul J. Jr. 1997. *A History of Corporate Finance*. New York: Cambridge University Press.

[8] Beck, Thorsten, Demirguc-Kunt, Asli, Levine, Ross. 2003. "Law and Finance: Why Does Legal Origin Matter?" *Journal of Comparative Economics* 31 (December): 653–75.

[9] Beck, Thorsten, Demirguc-Kunt, Asli, Levine, Ross. 2005. "Law and Firms' Access to Finance." American Law and Economic Review 7 (Spring): 211–52.

[10] Beck, Thorsten, Levine, Ross, Levkov, Alexey. 2010. "Big Bad Banks? The Winners and Losers from U.S. Branch Deregulation." *Journal of Finance*, forthcoming.

[11] Bencivenga, Valerie, Smith, Bruce. 1991. "Financial Intermediation and Endogenous Growth." *Review of Economics Studies* 58, 195-209.

[12] Black, Sandra E., Strahan, Philip E. 2002. "Entrepreneurship and Bank Credit Availability." *Journal of Finance* 57, 2807-2832.

[13] Bodenhorn, Howard. 2003. *State Banking in Early America: A New Economic History*. Cambridge University Press, New York.

[14] Boyd, John H., Prescott, Edward C. 1986. "Financial Intermediary-Coalitions." *Journal of Economic Theory* 38, 211-232.

[15] Braudel, Fernand. 1992. *Civilization and Capitalism, 15th - 18th Centuries, Vol. II: The Wheels of Commerce*. Berkeley, CA: University of California Press.

[16] Carosso, Vincent P. 1970. *Investment Banking in America: A History*. Cambridge, MA.: Harvard University Press.

[17] Chandler, Alfred D., Jr. 1954. "Patterns of American Railroad Finance, 1830-50", *The Business History Review* 28(3), 248-263.

[18] Chandler, Alfred D., Jr. 1965. "The Railroads: Pioneers in Modern Corporate Management", *The Business History Review* 39(1), 16-40.

[19] Chandler, Alfred D., Jr. 1977. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge, MA: Harvard University Press.

[20] Dell'Ariccia, Giovanni, Igan, Deniz, Laeven, Luc. 2008. "Credit Booms and Lending Standards: Evidence from the Subprime Mortgage Market." mimeo, International Monetary Fund.

[21] De la Fuente, Angel, Marin, Jose M. 1996. "Innovation, Bank Monitoring, and Endogenous Financial Development." *Journal of Monetary Economics* 37, 49-71.

[22] Galetovic, Alexander. 1996. "Specialization, Intermediation, and Growth." *Journal of Monetary Economics* 38, 549-559.

[23] Gennaioli, Nicola, Shleifer, Andrei. 2007. "The Evolution of the Common Law." *Journal of Political Economy* 115(1): 43-67.

[24] Graham, B, Dodd, D. 1934. *Security Analysis*. New York: Whittlesey House.

[25] Greenwood, Jeremy, Jovanovic, Boyan. 1990. "Financial Development, Growth, and the Distribution of Income." *Journal of Political Economy*. 98, 1076-1107.

[26] Greenwood, Jeremy, Sanchez, Juan M., Wang, Cheng. 2010. "Financial Development: The Role of Information Costs." *American Economic Review,* forthcoming.

[27] Goetzmann, William N. 2009. *Financing Civilization*. mimeo, Yale University.

[28] Goetzmann, William N. 2005. "Fibonacci and the Financial Revolution." In: *The Origins of Value: The Financial Innovations that Created Modern Finance*, Eds: William N. Goetzmann and K. Geert Rouwenhorst. New York: Oxford University Press, p. 123-143.

[29] Goetzmann, William N., Rouwenhorst, K. Geert. 2005. *The Origins of Value: The Financial Innovations that Created Modern Finance*. New York: Oxford University Press.

[30] Gompers, Paul, Lerner, Josh. 2001. "The Venture Capital Revolution." *Journal of Economic Perspectives* 2(1): 145-168.

[31] Jayaratne, Jith, Strahan, Phillip E. 1998. "Entry Restrictions, Industry Evolution, and Dynamic Efficiency: Evidence from Commercial Banking." *Journal of Law and Economics* 41 (April): 239-73.

[32] Harris, Ron. 1994. "The Bubble Act: Its Passage and Its Effects on Business Organization." *The Journal of Economic History* 54 (3): 610-627.

[33] Harris, Ron. 1997. "Political Economy, Interest Groups, Legal Institutions and the Repeal of the Bubble Act in 1825." *Economic History Review* 50(4): 675-696.

[34] Harris, Ron, 2000. *Industrializing English Law: Entrepreneurship and Business Organization, 1720-1844*. Cambridge, MA: Cambridge University Press.

[35] Hubbard, Glenn R., Palia, Darius. 1995. "Executive Pay and Performance: Evidence from the U.S. Banking Industry." *Journal of Financial Economics* 39 (September): 105-30.

[36] Kerr, William, Nanda, Ramana. 2009. "Democratizing Entry: Banking Deregulations, Financing Constraints, and Entrepreneurship." *Journal of Financial Economics,* forthcoming.

[37] Keys, Benjamin, Mukherjee, Tanmoy, Seru, Amit, Vig, Vikrant. 2010. "Did Securitization Lead to Lax Screening? Evidence from Subprime Loans." *Quarterly Journal of Economics* 125(1).

[38] King, Robert, Levine, Ross. 1993. "Finance, Entrepreneurship, and Growth: Theory and Evidence." *Journal of Monetary Economics* 32, 513-542.

[39] Kuran, Timur. 2009. "The Scale of Entrepreneurship in Middle Eastern History: Inhibitive Roles of Islamic Institutions," in *Entrepreneurs and Entrepreneurship in Economic History*, Eds: William J. Baumol, David S. Landes, and Joel Mokyr, (Princeton, NJ: Princeton University Press).

[40] Levine, Ross. 1991. "Stock Markets, Growth, and Tax Policy." *Journal of Finance* 46, 1445-1465.

[41] Levine, Ross. 2005a. "Finance and Growth: Theory and Evidence." In: *Handbook of Economic Growth,* Eds: Philippe Aghion and Steven N. Durlauf. Elsevier North-Holland. Publishers. 866-934.

[42] Levine, Ross. 2005b. "Law, Endowments, and Property Rights." *Journal of Economic Perspectives* 19(3), 61-88.

[43] Lopez, Robert S. 1976. *The Commercial Revolution of the Middle Ages, 950-1350.* New York: Cambridge University Press.

[44] Loutskina, Elena, Strahan, Philip E. 2009. "Securitization and the Decline of Bank Finance on Loan Supply: Evidence from Mortgage Originations." *Journal of Finance* 64(2): 861-889

[45] Malmendier, Ulrike. 2009. "Law and Finance at the Origin." *Journal of Economic Literature*, forthcoming.

[46] Merton, Robert C. 1995. "Financial Innovation and the Management and Regulation of Financial Institutions." Journal of Banking and Finance 19: 461-481.

[47] Mian, Atif, Sufi, Amir. 2009. "The Consequences of Mortgage Credit Expansion: Evidence from the 2007 Mortgage Default Crisis." *Quarterly Journal of Economics* 124(4).

[48] Neal, Larry.1990. *The Rise of Financial Capitalism: International Capital Markets in the Age of Reason.* New York: Cambridge University Press.

[49] Obstfeld, Maurice. 1994. "Risk-Taking, Diversification, and Growth." *American Economic Review* 84(5): 1310-1329.

[50] Romer, Paul M. 1986. "Increasing Returns and Long-Run Growth." *Journal of Political Economy* 94(5): 1002-1037.

[51] Romer, Paul M. 1990. "Endogenous Technological Change." *Journal of Political Economy* 98(5): S71-102.

[52] Schweitzer, Stuart. 2006. *Pharmaceutical Economics and Policy*. New York: Oxford University Press.

[53] Tufano, Peter. 1997. "Business Failure, Judicial Intervention, and Financial Intervention: Restructuring U.S. Railroads in the Nineteenth Century." *The Business History Review* 71(1), pp. 1-40.

[54] Tufano, Peter. 2003. "Financial Innovation." In: *Handbook of the Economics of Finance (Volume 1a: Corporate Finance)*. Eds: George Constantinidis, Milton Harris, and Rene Stulz. Elsevier North-Holland. 307-336.

Table 1. 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 financial innovation. The dependent variable is the growth rate of real per capita GDP minus the real per capital GDP growth rate of the US, 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 financial innovation, measured as the growth rate of private credit to GDP over 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 financial innovation, f. In regression (3), we use IVs for F, f, and the interactive terms, F(y-y1) and f(y-y1), where the instruments are legal origin, the change in the Abiad and Mody (2005) financial reform index over the period 1973-1995, and the interactions between the initial real per capital GDP gap with the United States (y-y1) and both the legal origin dummy variables and the change in the financial reform index. We are missing data on financial reform index for 9 countries. The IVs in regression (4) are the legal origin dummy variables and the interaction between legal origin and the initial real per capital GDP gap with the United States. ***, **, 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	-0.305	0.233	-0.261
	(0.529)	(0.404)	(0.598)	(0.517)
F	-0.005	0.000	0.003	
	(0.007)	(0.006)	(0.008)	
F (y - y1)	-0.030**	-0.032**	-0.017	
	(0.013)	(0.014)	(0.020)	
f		0.047	0.037	0.001
		(0.083)	(0.167)	(0.168)
f (y - y1)		-0.091**	-0.310***	-0.240*
		(0.041)	(0.105)	(0.137)
Average years of schooling in 1960	0.200*	0.178*	-0.007	0.125
	(0.112)	(0.097)	(0.114)	(0.116)
Government size	0.013	0.004	0.010	-0.020
	(0.041)	(0.038)	(0.031)	(0.031)
Inflation	-0.001	0.011	-0.000	0.014
	(0.014)	(0.010)	(0.009)	(0.011)
Black market premium	-0.017***	-0.012**	0.004	-0.008
	(0.005)	(0.005)	(0.004)	(0.006)
Openness to trade	0.015**	0.009	-0.006	0.002
	(0.006)	(0.006)	(0.007)	(0.006)
Revolutions and coups	-1.435	-2.553**	-3.487**	-4.104**
	(0.959)	(0.992)	(1.570)	(1.706)
Political assassinations	-0.007	0.036	0.287	0.343
	(0.285)	(0.325)	(0.521)	(0.467)
Ethnic diversity	-0.064	0.197	-2.378**	-0.556
	(0.986)	(0.936)	(0.951)	(0.933)
Constant	-2.172*	-2.195**	0.291	-0.610
	(1.183)	(0.953)	(1.650)	(1.127)
Hansen J-test (p-value)	--	--	0.26	0.19
Observations	56	56	47	56
R-squared	0.558	0.682	0.371	0.398