Financial Innovation and Endogenous Growth*

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Abstract

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. A novel feature of the model is that financiers can engage in the costly and risky process of inventing better processes for screening entrepreneurs. Successful financial innovators screen entrepreneurs better than other financiers, generating monopoly rents. A particular screening process becomes less effective as technology advances. Consequently, technological innovation and economic growth will eventually stop unless financiers innovate. Rather than stressing the level of financial development, we highlight the vital role of financial innovation in supporting economic growth.

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

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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 and innovation (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 along with new financial reports, accounting systems, and performance criteria 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 novel activities (Graham and Dodd, 1934; Allen and Gale, 1994; and Tufano, 2003). More recently, financial entrepreneurs created venture capitalist firms to screen high-tech inventions and guide new entrepreneurs.

Yet, models of economic growth frequently ignore financial innovation and instead take the financial system as given and inert. Most frequently, financial arrangements are added to core models of endogenous technological change developed by Romer (1986, 1990) and Aghion and Howitt (1991; 2009). For example, in King and Levine (1993), Galetovic (1996), and Aghion, Howitt, and Mayer-Foulkes (2005), the financial system affects the rate of technological innovation and thus of economic growth by determining the frequency at which society allocates funds to those entrepreneurs with the highest probability of successfully innovating. In Bencivenga and Smith (1991) and Levine (1991), finance influences long-run growth by affecting the risk of investing in high-return projects. In these models, however, financial contracts, markets, and intermediaries do not emerge and evolve endogenously with technological change.

Even in models where financial arrangements arise endogenously, financial innovation is not spurred by the same purposeful profit motive underlying technological innovation. In Greenwood and Jovanovic (1990), financial intermediaries produce information about investment project, affecting resource allocation and growth. Since there is a fixed cost to joining financial intermediaries, growth means that more individuals can join the intermediary. Thus,
growth and the fraction of the population that has joined a financial intermediary evolve together until everyone has joined the intermediary. In Greenwood and Jovanovic (1990), however, financial intermediaries do not purposefully engage in innovative behavior designed to capture monopoly rents by improving the quality of financial services. Greenwood, Sanchez, and Wang (2007) make an important contribution by developing a model in which financial intermediaries invest resources to monitor firms. When financial institutions invest more resources, this improves the monitoring technology, enhancing capital allocation and growth. We build on this line of work by treating financiers as profit seeking entrepreneurs that choose to make costly, risky investments, such as designing new financial instruments, creating new corporate structures, or developing new screening techniques.

In this paper, 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 textbook model of Shumpeterian growth, where entrepreneurs seek to extract monopoly profits by engaging in the costly and risky process of inventing new goods and production methods (Aghion, Howitt, and Mayer-Foulkes, 2005; and 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 financiers 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 competitor financiers. Successful financial innovation, therefore, generates monopoly rents for the financier, just as successful technological innovation generates monopoly rents for the technological entrepreneur.

A second noteworthy feature of the model is that every particular screening methodology becomes less effective at identifying promising entrepreneurs as technology advances. For example, the technology for screening ship building was less effective at screening railroads, and the technology for screening pharmaceuticals in the 1960s is inappropriate 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 (a) develop specialized investment banks, new contracts, and more elaborate reporting standards to screen railroads and (b) create venture capital firms to better evaluate and monitor new high-tech firms. Financial and technological innovation are inextricably linked.

A central finding of the paper is that technological innovation and economic growth will
eventually stop unless financiers innovate. Without financial innovation, the existing screening technology will become increasingly obsolete as technological innovation continues. Eventually, financiers will become so poor at screening entrepreneurs that the probability of identifying successful entrepreneurs, and hence investment in entrepreneurial innovation, will fall 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.

From a policy perspective, the paper focuses on adaptability and innovation. In the model, growth will eventually slow and stop regardless of the level of financial development in the absence of financial and technological innovation. Legal, regulatory, or policy impediments to financial innovation will stymie technological innovation and economic growth in the long-run. Rather than stressing policies that support a particular level of financial development, the theory highlights the efficacy of policies that facilitate efficient improvements in screening technologies.

History provides supportive examples. For example, 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 or adoption of new financial arrangements, such as the limited liability corporation, to pool and administer the funds of thousands of investors. According to Kuran (2006), the Islamic system stymied financial innovation and severely hindered technological innovation and growth. Harris (1994; 1997; 2000) also stresses that legal impediments to financial innovation, especially limits on the creation of limited liability corporations, temporarily stymied economic growth in England and France in 18th and 19th centuries. Similarly, 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 (Jayaratne and Strahan, 1996; Kroszner and Strahan, 1999; and Beck, Levine, and Levkov, 2009).

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 or enhancing the governance of firms. We also do not consider how financial arrangements mitigate the moral hazard and adverse selection problems arising from informational asymmetries. We do not
argue that these essential financial functions are unimportant, nor do we argue that they are less important than screening. Rather, we focus on one critical financial function: acquiring and processing information about investments before they are funded. We develop a model in which profit maximizing financial and technological entrepreneurs interact to shape the rate of economic growth. The predictions emerging from the model fit historical experiences better than existing models of finance and growth.

2 The Basic Structure of the Model

We cast Shumpeterian growth theory in an overlapping-generations economy closely following the formulation of Aghion, Howitt and Mayer-Foulkes (2005), denoted as AHM for brevity. Economic activity extends over infinite discrete time. There are \( k \) countries. Exchange of goods and financial services are not allowed across-countries, however technological ideas developed in one country may be used by another one.\(^1\) There is a continuum of individuals in each country whose fixed population is normalized to 1, consequently aggregate and per capita quantities coincide. Each individual lives two periods and is endowed with three units of labor in the first period of her life and none in the second. The utility function in linear in consumption with \( U = c_1 + \beta c_2 \), with \( \beta \in (0, 1) \). The following section shows how the economy evolves over time for a given country.

2.1 Production of 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:

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

where \( x_{t,i} \) is the amount of latest version of the intermediate good \( i \) with a technological level of \( A_{t,i} \). \( P \) is the labor normalized to 1. The general good \( Z \) is used for consumption, an input to the R&D of the intermediate goods sector and the financial sector and finally as an input in the production of intermediate goods.

The production of the final good, used as the numeraire, is taking place under perfectly competitive terms, thus the price of each intermediate good equals its marginal product:

\(^1\)Allowing for international trade in financial services does not change the predictions of the model. We make the assumption, however, because financial systems operate within a country’s specific institutional setting and thus, financial technologies related to the screening of entrepreneurial projects are arguably imperfectly transferable across economies.
\[ p_{t,i} = \alpha \left( \frac{A_{t,i}}{x_{t,i}} \right)^{1-\alpha} \] (2)

2.2 Intermediate Goods Sectors

In each intermediate goods sector \( i \) there exists one person born in period \( t-1 \) who is capable of producing an innovation for the next period \( t \). This individual is called the \( i^{th} \) potential innovator in period \( t-1 \). How this capable entrepreneur is chosen will become clear in the next section. Let \( \mu_{t,i} \) be the probability that she succeeds in innovating. Then:

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

where \( \bar{A}_{t,i} \) is the world technology frontier. This grows at a constant rate \( g \), taken as given for now. Should the capable entrepreneur be successful in innovating, that is implementing the world frontier technology for good \( i \), she is able to produce this intermediate good using as the sole input in the production one unit of the final good per unit of intermediate good. In every intermediate sector there exists an unlimited number of people that are able to produce the intermediate good at the technological level of the latest innovation at a unit cost of \( \chi > 1 \).

This setup implies that in sectors where the potential innovator is successful he becomes the sole producer charging a price equal to the unit cost of the competitive fringe. In the rest of the sectors where entrepreneurial innovation did not occur, production will take place under perfectly competitive terms with the price being equal to the unit cost of the competitive fringe. In either case the price, \( p_t(i) \), will equal \( \chi \). Using the demand function for intermediate goods in (2), the quantity demanded for intermediate good \( i \) will be:

\[ x_{t,i} = \left( \frac{\alpha}{\chi} \right)^{\frac{1}{1-\alpha}} A_{t,i} \] (3)

Consequently, the unsuccessful innovator of period \( t-1 \) will earn zero profits in period \( t \) whereas a successful one will generate profits equal to \( \pi_{t,i} = \pi \bar{A}_{t,i} \) with \( \pi = (\chi - 1) \left( \frac{\alpha}{\chi} \right)^{\frac{1}{1-\alpha}} \).

2.3 Financiers

The analysis so far follows precisely the model of AHM. The fundamental difference lies in the role and the evolution of the financial system. It in is the selection of the potential innovator in each intermediate sector \( i \) where the financiers play a fundamental role.
In particular, the selection of the capable entrepreneur at a given intermediate sector takes place as follows: In the beginning of each period $t - 1$ a continuum of individuals each one endowed with an entrepreneurial idea is born. These are the nonrated entrepreneurs. Among those only one has the potential of successfully innovating. The rest are effectively "lemons", that is, they never deliver a successful innovation.\footnote{We adopt this stark representation for simplicity. Assuming a different distribution for the quality of projects would not change the qualitative predictions.} The quality of each idea is unknown both to the nonrated entrepreneur and the households. These nonrated projects are the primitive inputs in the innovation process for intermediate goods.

In this environment the key activity of the financiers is the provision of information for the underlying quality of the nonrated entrepreneurs. This dimension of the financial system as a provider of screening for the potential entrepreneurs is in the spirit of the work by King and Levine (1993). Note that in absence of information regarding the quality of a project a nonrated entrepreneur will not engage in any innovating activity, nor the households would be willing to lend any resources to an nonrated project since the probability of the project being potentially successful is of measure zero.

In period $t - 1$ in each intermediate sector $i$ a single financier is born with the potential to innovate in period $t - 1$.\footnote{Here we do not attempt to endogenize the emergence of the financial system. We take its existence for granted focusing on the interaction between financial and entrepreneurial innovation.} A successful financial innovation in sector $i$ allows the respective financier to perfectly screen the pool of nonrated projects and identify the potential innovator with probability 1.

In the beginning of each period the nonrated entrepreneurs in sector $i$ report their projects to the financier. The selection among the nonrated entrepreneurs requires the use of a screening technology. The financier by investing in $R&D$ is capable of innovating, that is improving the level of screening technology to be used in assessing the quality of the nonrated entrepreneurs.

Let $\mu^F_{t,i}$ be the probability of successful financial innovation, that is the probability that a financier in period $t - 1$ screens successfully the entrepreneurial projects in her sector that aspire to innovate at the level of the frontier technology in period $t$. Also, define $m_{t,i}$ the level of financial know-how available for screening the nonrated projects in period $t - 1$ in intermediate...
sector \( i \).\(^4\) Then:

\[
m_{t,i} = \begin{cases} 
    \bar{A}_t & \text{with probability } \mu^f_{t,i} \\
    m_{t-1,i} & \text{with probability } 1 - \mu^f_{t,i}
\end{cases}
\] (4)

The fact that a successful financial innovation brings the screening technology up to par with the world technology frontier, \( \bar{A}_t \), is a manifestation that the financier is able to correctly identify the potential innovator for period \( t \).\(^5\) On the other hand, if the financial innovator is unsuccessful then the screening technology available to the financier in sector \( i \) in period \( t - 1 \) is the level of screening technology of period \( t - 1 \), \( m_{t-1,i} \).

Assuming that the probability the financier in sector \( i \) correctly identifies in period \( t - 1 \) the potential innovator who aspires to innovate at the technology frontier in period \( t \), \( \lambda_{t,i} \), is a linear function of the ratio of screening technology in sector \( i \) in period \( t \) relative to the world technology frontier in period \( t \) and manipulating (4) accordingly one obtains:

\[
\lambda_{t,i} = \frac{m_{t,i}}{A_t} = \begin{cases} 
    \frac{\bar{A}_t}{A_t} = 1 & \text{with probability } \mu^f_{t,i} \\
    \frac{m_{t-1,i}}{A_t} = \frac{1}{1+g} \lambda_{t-1,i} & \text{with probability } 1 - \mu^f_{t,i}
\end{cases}
\] (5)

Consequently, a successfully innovating financier in sector \( i \) in period \( t - 1 \) will choose the entrepreneur capable of delivering an innovation in period \( t \) with probability \( 1 \). On the other hand, in a sector with a non-innovative financier the probability of correctly identifying the potential entrepreneur is the ratio of that sector’s screening capacity as of period \( t - 1 \), \( m_{t-1,i} \), relative to the technological frontier of period \( t \). This is sector’s \( i \) relative financial efficiency, \( \lambda_{t,i} \), or alternatively an inverse index of the sector’s financial gap.

Such specification uncovers the interaction of two elements that form the basis of the proposed theory. Namely, in non-financially innovating sectors conditional on a level of financial know-how, \( m_{t,i} \), an increase in the intermediate good’s frontier technology will limit the ability of the financier to screen effectively the nonrated entrepreneurs, that is, as technology of the intermediate goods improves, these new sophisticated and complex technologies

\(^4\)Each intermediate sector has its own specific monitoring technology, implying that the requirements for the screening process differs across sectors. For example, internet startup’s screening requirements differ from those needed for shoe making. This specificity of screening process implies that entrepreneurs and financiers from one sector do not have the incentive to solicit and acquire the financial know how available in other sectors.

\(^5\)One way to motivate why the level of financial know-how reaches the level of the real frontier technology is the following: Suppose that for an entrepreneurial innovation to succeed there are several dimensions that need to be correctly executed. Naturally, the more advanced is the level of technology there are both more dimensions and/or more complexity involved. Since the role of the financier is to estimate the viability of an entrepreneurial idea he has to screen the project along these new dimensions. Such requirement necessitates that he has to come up with new tools, like alternative contractual arrangements or new information blue prints, that will improve his screening capacity along the frontier technology lines.
gradually render the screening capacity of the financial intermediaries obsolete. Similarly, conditional on the level of the intermediate good’s frontier technology an increase in the level of monitoring technology, \( m_{t,i} \), will enhance the ability of financiers to correctly identify the able entrepreneurs.

## 2.3.1 Financiers and Entrepreneurs

The nonrated entrepreneurs in sector \( i \) in period \( t - 1 \) may obtain screening information either by resorting to the sector specific financier or to an unlimited number of individuals who have access to the financial technology of sector \( i \) in period \( t - 1, m_{t-1,i} \). This competitive fringe of individuals is able to successfully screen the nonrated projects with probability \( \lambda_{t-1,i} \). \[^{6}\]

In either case the rated entrepreneur credibly commits to repay the provider of the evaluation a fraction of her net revenue if she successfully innovates. Thus, the legal environment within which contracts are signed is perfectly enforceable.

The successfully innovating financier generates profits by getting a fraction, \( \delta_{t,i} \), of the entrepreneurial profits. This fraction is endogenously determined in the model. In particular, in sectors where the financiers have innovated, they will be the sole providers of screening, charging a price equal to the fraction of the entrepreneur’s expected profits such that the latter is indifferent between being screened by the successful financier or getting the screening from the individuals who have free access to the standard financial technology. For simplicity we assume that the provision of the standard screening has zero cost which coupled with the assumption of perfect competition guarantees that the entrepreneurs who opt for the standard screening get to keep all the profits in case of successful innovation.

So, the timing of events unfolds as follows: At the beginning of each period \( t - 1 \) in each sector the nonrated entrepreneurs present their projects to the potential financier. The financier borrows money from the households and invests in financial innovation. Should the financial innovation fail then the able entrepreneur is identified using the standard screening technology available in period \( t - 1 \). Subsequently, the chosen good’s entrepreneur chooses how much to invest in innovation. In period \( t \) uncertainty is resolved. If the project is successful the entrepreneur pays the contracted fraction of his profits to the financier, repays the cost of innovation and keeps the profits.

The key difference from the point of view a rated entrepreneur and the lending households

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\[^{6}\]This assumption maintains the symmetry between entrepreneurs and financiers, that is, both the production of standard screening and the production of the latest technology intermediate goods may be supplied by a competitive fringe, rendering zero the profits that can be made by unsuccessful innovators.
is that if the financier in the respective sector has successfully innovated then the entrepreneur with the potentially successful project is known with certainty, whereas if the financier did not innovate then the potential entrepreneur is picked with probability $\lambda_{t,i} < 1$. Figure 1 below summarizes all possible scenarios.

Figure 1: Timing of Events

### 2.4 Entrepreneurial Innovation

The production of entrepreneurial innovation depends on the $R&D$ investment an entrepreneur in sector $i$ makes in period $t-1$. In order to innovate at a given rate $\mu_{t,i}$, the amount of investment is governed by the following cost function:

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

where $N_{t-1,i}^e$ stands for the units of the final good that must be used up for goods' innovation. As in AHM the cost of innovation increases proportionally to the world technology frontier capturing the fishing out effect. That is the further the frontier moves forward the more expensive becomes to keep on innovating at the same rate $\mu_{t,i}^e$. 

10
In equilibrium each innovating entrepreneur will choose $\mu^e_{t,i}$ in order to maximize expected profits. Note that given the contractual agreement assumed between the entrepreneur and the financier the innovating entrepreneur gets to keep a fraction $(1 - \delta_{t,i})$ of the expected profits $\Pi^e_{t,i}$:

$$\Pi^e_{t,i} = (1 - \delta_{t,i}) \left( \beta \mu^e_{t,i} \pi A_t - N^e_{t-1,i} \right)$$  \hspace{1cm} (6)

Importantly, rated entrepreneurs and financial innovators have unlimited access to outside finance,\(^7\) that is they are not constrained by their income level.

In case of successful financial innovation the rated entrepreneur knows with probability 1 that she is the potential incumbent. In this case the profit maximizing probability is the following\(^8\):

$$\mu^e_{t,i} = \left( \frac{\beta \pi}{\gamma \theta^\gamma} \right)^{1/(\gamma-1)}$$  \hspace{1cm} (7)

Note that since innovating entrepreneurs repay the financiers only when they are successful, the fraction $\delta_{t,i}$ of the expected profits that needs to be repaid does not affect the probability of entrepreneurial innovation.\(^9\) A cursory inspection of (7) shows that entrepreneurial innovation under perfect screening has intuitive comparative statics, that is the higher is the net profit per unit of the intermediate good, $\pi$, and/or the less costly is entrepreneurial innovation i.e. a lower $\theta$, the higher is the profit maximizing entrepreneurial probability. Also, as long as $\pi$ and $\theta$ are common across sectors it follows that $\mu^e_{t,i} = \mu^{es}_i \nabla_i$.

Substituting (7) in (6) one derives the net expected profits of a perfectly rated entrepre-

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\(^7\) Each innovator can borrow unlimited quantities at an interest rate $r = 1/\beta - 1$ which he is bound to repay. In particular young people, who are the only guys with money in the economy able to lend money, extend several types of loans depending on who is the receiver. Since they are risk neutral they extend loans as long as the expected rate of return equals to $r = \beta^{-1} + 1$. The following are the arbitrage conditions that the interest factors need to satisfy:

- Case 1 - Interest factor charged to an innovating financier:
  $$R^t_i = \frac{1+r}{\mu_i^t \mu_i^t}$$

- Case 2 - Interest factor charged to an entrepreneurs rated by successful financiers:
  $$R^e_i = \frac{1+r}{\mu_i^e}$$

- Case 3 - Interest factor charged to an entrepreneur rated by a non successful financier:
  $$R^c_i = \frac{1+r}{\mu_i^c \mu_i^c}$$

\(^8\) Here we make the assumption that $\beta \pi < \gamma \theta^\gamma$ to ensure that the equilibrium entrepreneurial probability under perfect financial screening is less than one, i.e. $\mu^{es}_i < 1$

\(^9\) Allowing for alternative contractual agreements requiring for example that a rated entrepreneur pays some amount in advance to the financier for the screening and its implications for financial and entrepreneurial behavior is an avenue for further research.
where $\varphi = \beta \pi (1 - 1/\gamma)$.

The fraction of profits the entrepreneur needs to repay, $1 - \delta_{t, i}$, is determined as follows. Since unrated entrepreneurs in sector $i$ in period $t - 1$ have free access to the sectorial financial capacity, $m_{t-1, i}$, it follows that they may choose to be screened by this imperfect technology and keep all the profits.

In this case the expected entrepreneurial profits are modified to incorporate the imperfection of the screening technology and the fact that the imperfectly rated entrepreneur gets to keep all the expected profits. Consequently, the expected net payoff of an imperfectly rated entrepreneur in sector $i$, $\Pi'^{e}_{t, i}$, is:

$$\Pi'^{e}_{t, i} = \beta \lambda_{t, i} \mu'^{e}_{t, i} \varphi \bar{A}_t - N_{t-1}$$

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

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

Substituting (10) in (9) one derives the maximal net expected revenue of an imperfectly rated entrepreneur, i.e.,

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

The following Lemma establishes the properties of entrepreneurial innovation in sector $i$ employing the standard financial technology, $\lambda_{t, i}$.

**Lemma 1** The properties of entrepreneurial innovation in sectors screened by the standard monitoring technology are:

1. Entrepreneurial innovation displays the same properties as entrepreneurial innovation in financially innovative sectors, i.e.,:

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

2. Entrepreneurial innovation is an increasing function of a sector’s relative financial efficiency, $\lambda_{t, i}$ i.e.,:

$$\frac{\partial \mu'^{e}_{t, i}}{\partial \lambda_{t, i}} > 0$$
Proof. These properties follow by directly differentiating (10) \(\Box\)

In order for the unrated entrepreneurs in the beginning of period \(t-1\) to be indifferent between choosing a contract with a financial innovator or using the available screening technology it must be the case that these two alternatives deliver the same expected profits.

In math (8) should equal (11), that is:

\[\delta_{t,t} = 1 - (\lambda_{t,i})^{\frac{1}{t-1}}\]  

(12)

Simple inspection of (12) reveals an interesting comparative static, that is, the higher is the level of the sectorial relative financial development \(\lambda_{t,i}\) the lower the fraction of profits an innovating financier in sector \(i\) may claim from a successful entrepreneur. This occurs because an advanced sectorial standard screening technology in period \(t\), if used, will evaluate correctly with high probability the unrated projects. This effectively increases the outside option of the entrepreneurs. On the other hand, a deteriorating sectorial relative efficiency allows for the innovating financier to get a larger fraction of the expected entrepreneurial profits.\(^{10}\) Since gross profits of a perfectly rated entrepreneur are independent of the relative financial efficiency, \(\Pi_{t,i}^{e*} = (1 - \delta_{t,i})\mu_{t,i}^{e*}\varphi\tilde{A}_t\), the fraction that may be claimed also determines the level of profits a financier generates.

2.5 Financial Innovation

Financial innovation in sector \(i\) requires R&D investment that a financier has to incur in order to innovate at a given rate \(\mu_{t,i}^{f}\). This is governed by the following cost function:

\[N_{t-1,i}^{f} = (\theta_{f}\mu_{t,i}^{f})^{\gamma}\tilde{A}_t, \quad \gamma > 1\]

where \(N_{t-1,i}^{f}\) stands for the units of the final good that must be used up for financial innovation. Since the pool of unrated projects that need to be screened in period \(t-1\) in sector \(i\) aspire to innovate at the world technology, \(\tilde{A}_t\), the cost of financial innovation increases proportionally to it.

\(^{10}\)This implication hinges on the assumption that innovative financiers live only for two periods and may obtain profits, if successful, only in the second period of their lives. This structure does not allow financiers to internalize the positive effect of the current period financial innovation on next period’s standard screening technology. Extending the model to incorporate long-lived financiers with property rights on both the short and long-run effects of financial innovation, would feature two counterbalancing forces. On the one hand, the increased horizon over which financiers may rip the benefits of their innovation would spur financial investments, whereas the fact that financiers could still derive profits by charging for the use of the standard financial technology would dampen financial innovation. Endogenizing both the length of property rights over financial and entrepreneurial innovations, through an optimal patent system for example, is a potential extension of the model.
The innovating financier will choose $\mu_{t,i}^f$ in order to maximize expected profits, $\Pi_{t,i}^f$. Note that given the contractual agreement assumed, the innovating financier gets to keep a fraction $\delta_{t,i}$ of the expected entrepreneurial profits, $\Pi_{t-1,i}^{e\ast}$, i.e.,

$$\Pi_{t,i}^f = \mu_{t,i}^f \beta \delta_{t,i} \Pi_{t,i}^{e\ast} - N_{t-1,i}^f$$  \hspace{1cm} (13)

Substituting (12) into (13) and maximizing the profit function of a financier we obtain the profit maximizing probability of financial innovation in sector $i$:11

$$\mu_{t,i}^f = \left( \frac{\beta \mu_{t}^{e\ast} \phi(1 - (\lambda_{t,i})^{\frac{\gamma}{1-r}})}{\gamma \theta_j^f} \right)^{\frac{1}{\gamma-r}}$$  \hspace{1cm} (14)

### 2.6 Aggregating the Financial System

Moving to a country level analysis we need to aggregate the behavior of entrepreneurs and financiers across individual sectors. In this section we focus on the overall functioning of the financial system.

The average relative financial efficiency within a country may be defined as:

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

In every period $t$ a sector $i$ will be facing its sector specific relative financial efficiency, $\lambda_{t,i}$. Nevertheless, since all sectors are identical with respect to the primitive characteristics of financial and entrepreneurial innovation in the steady state every sector will be facing on average the relative financial efficiency, $\lambda_t$. Thus, in equilibrium each sector will have on average the same probability of financial innovation, i.e., $\mu_{t,i}^f = \mu_t^{f\ast}$

Consequently, taking into account (5) a country’s relative financial efficiency evolves as follows:

$$\lambda_t = \mu_t^f + (1 - \mu_t^f) \frac{\lambda_{t-1}}{1 + g}$$  \hspace{1cm} (15)

The law of motion for $\lambda_t$ shows that in period $t$ an economy’s relative financial efficiency will equal 1 in fraction $\mu_t^f$ of the sectors that innovated successfully in period $t-1$, however, in the unsuccessful sectors, $1 - \mu_t^f$, it remain equal to $\lambda_{t-1}$.12 Note that the relative efficiency

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11 In order to ensure that the rate of financial innovation is always less than 1 is sufficient to assume that $\theta_j > \theta$.

12 To be sure in every single period in equilibrium each sector will be having a different innovation probability $\mu_{t,i}^f$, nevertheless, this probability on average will equal the average innovation probability, $\mu_t^{f\ast}$, which is derived by substituting (16) in (14).
bequeathed from period $t-1$ is eroded by a factor of $1+g$ capturing the fact that between $t-1$ and $t$ the advancement of the world technology frontier. Overall, $\lambda_t$ is the average probability at which potential innovators who belong to the non-financially innovating sectors are identified by the standard screening technology and is a measure of a country’s financial capacity relative to the technological frontier, or an inverse measure of its "financial gap".

One may obtain the steady state level of financial gap by substituting $\lambda_t = \lambda_{t-1} = \lambda^*$ and $\mu_t^f = \mu_t^{f*}$ and solve for $\lambda^*$ in (15):

$$\lambda^* = \frac{\mu_t^{f*}}{g + \mu_t^{f*}}$$

(16)

Directly differentiating (16) reveals an important comparative static of this economy:

$$\frac{\partial \lambda^*}{\partial \mu_t^{f*}} > 0$$

(17)

The higher is the rate of financial innovation, $\mu_t^{f*}$, the larger is the steady state level of the economy’s relative financial efficiency.

Naturally, the steady state profit maximizing innovation probability of the financial system is determined by replacing $\lambda_{t,i} = \lambda^*$ into (14), i.e.:

$$\mu_t^{f*} = \left( \frac{\beta \mu_t^{f*} \phi (1 - (\lambda^*)^{\frac{\gamma}{\gamma+\tau}})}{\gamma \theta_f^i} \right)^{\frac{1}{\gamma+\tau-1}}$$

(18)

and finally combining (16) and (18). Doing so one obtains the implicit function

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

(19)

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, i.e.,:

$$\frac{\partial \mu_t^{f*}}{\partial \mu_t^{e*}} > 0.$$  

2. Financial innovation is a decreasing function of the costs of financial innovation, $\theta_f$, i.e.,:

$$\frac{\partial \mu_t^{f*}}{\partial \theta_f} < 0.$$
3. Financial innovation is an increasing function of the rate at which the world technology frontier, $g$, improves i.e.,:

$$\frac{\partial \mu_t^f}{\partial g} > 0$$

Proof. Repeated use of the Implicit Function Theorem and differentiating accordingly delivers the results.

The properties of the equilibrium financial innovation offer new insights into the so far neglected nexus between entrepreneurial and financial innovation. Sectors with laggard entrepreneurial activity offer little incentives to the financiers in these sectors to provide efficient screening endogenously delaying financial innovation. It follows that interventions affecting the entrepreneurial sector have direct repercussions on the incentives of the financiers with subsequent feedback effects on entrepreneurial activity.

It is also important to stress that financial innovation affects entrepreneurial innovation both directly and indirectly. The direct effect comes from perfectly identifying the right entrepreneur, thus inducing the highest investment in entrepreneurial innovation. The indirect effect comes from the positive effect that an increase of financial innovation has on the relative financial efficiency of all subsequent periods, see (17). This essentially improves the odds at which entrepreneurs in non-financially innovating sectors are correctly identified inducing higher investment in entrepreneurial activity. This becomes evident by seeing the second part of Lemma 1.

This two way relationship between entrepreneurial and financial innovation gives rise to a multiplier effect associated with a change in entrepreneurial innovation. More precisely, following an increase in entrepreneurial activity, $\mu_t^e$, the immediate effect will be an increase in financial innovation which will cause an increase in the steady state level of financial efficiency further enhancing the incentive’s of entrepreneurs creating a virtuous cycle. This example shows that financial and entrepreneurial behavior are inextricably linked and has implications on how to interpret existing findings on the relationship between financial development and economic performance.

Impediments to financial innovation have a large effect on growth. In particular, the cost of financial innovation $\theta_f$ affects the rate of financial and hence technological innovation. Thus, countries in which it is more expensive to innovate financially (higher $\theta_f$) will tend to grow more slowly than economies with lower barrier 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).

2.7 The Economy in the Aggregate

A country’s "average productivity" may be defined as

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

Substituting (3) into (1) the gross amount of the general good is given by

$$ Z_t = \zeta A_t $$

where

$$ \zeta = (\alpha/\chi)^{\alpha/(1-\alpha)} $$

In equilibrium both entrepreneurial and financial innovation will be on average the same across sectors: $\mu^f_{t,i} = \mu^f_t$ and $\mu^{\ell}_{t,i} = \mu^\ell_t$. Consequently, the following equation gives the law of motion for the average productivity within a country:

$$ A_t = (\mu^f_t \mu^\ell_t + (1 - \mu^f_t)\lambda_t \mu^\ell_t)\bar{A}_t + \left(1 - \lambda_t \mu^\ell_t - \mu^f_t \mu^\ell_t + \mu^f_t \lambda_t \mu^\ell_t\right)A_{t-1} $$

(20)

Deriving (20) becomes simple by reading off the branches of Figure 1. The average productivity in period $t$ of a country is a weighted average of sectors which implement the frontier technology, $\bar{A}_t$, and of sectors using the average productivity of period $t - 1$. These weights are respectively functions of the probability of financial innovation in period $t$, entrepreneurial innovation in period $t$, and a country’s relative financial efficiency, $\lambda_t$. In particular, the productivity parameter will equal $\bar{A}_t$ in those sectors where both financiers and entrepreneurs innovated successfully last period, and in the sectors where although the financiers did not financially innovate, $1 - \mu^f_t$, the nonrated projects where both correctly screened by the standard screening technology and the screened entrepreneurs were successful.

Since by assumption the final goods production sector is competitive, the wage rate $w_t$ will be the marginal product of labor in the production of the final good, i.e.

$$ w_t = (1 - \alpha)Z_t = (1 - \alpha)\zeta A_t $$

Note that 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 fact plays no role in determining entrepreneurial investment. In fact, as it is shown in (7) and (10) probability of innovation depends only on entrepreneurial profits and the level of the standard financial know how available to the non-financially innovating sectors. Domestic productivity only determines the amount that a financier and an entrepreneur get to borrow from the households in period $t$. Since neither financiers nor entrepreneurs may hide
the proceeds, households are willing to lend any amount at the respective interest rates. See, footnote 7 for the determination of the interest rates charged to different parties.

Value added in the general sector is wage income whereas the value added in the good’s and financial sectors are profit income. Per capita gross domestic product is the sum of added value across sectors:

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

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

### 2.7.1 Growth Rate in a Closed Economy

The steady state growth rate in a closed economy (or the technologically leading economy in a multi-country model) is determined by the equilibrium rate of entrepreneurial innovations. That is,

\[ g = \mu^f \mu^e + (1 - \mu^f) \lambda^* \mu^e \]

### 2.8 Economic Performance Across Countries

Let \( a_t = \frac{A_t}{\bar{A}_t} \) denote a country’s gap from the technology frontier. Each country takes the evolution of the frontier as exogenous. Then, it follows that the technology gap evolves according to:

\[ a_{t+1} = (\mu^e_{t+1} + (1 - \mu^f_{t+1}) \lambda_{t+1} \mu^e_{t+1}) \bar{A}_{t+1} + \frac{1 - \lambda_{t+1} \mu^e_{t+1} - \mu^f_{t+1} \lambda_{t+1} \mu^e_{t+1}}{1 + g} \]

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

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

where \( \mu^s = \mu^f \mu^e + (1 - \mu^f) \lambda^* \mu^e \) is the fraction of entrepreneurially innovating sectors.

The following Proposition summarizes the properties of the model economy

**Proposition 1** The steady state technology gap of an economy displays the following properties:
1. An economy blocking financial innovation will eventually stagnate irrespective of the initial level of financial gap, $\lambda_t$.

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

Steady state technology gap is increasing at the rate of financial innovation, $\mu^f$, i.e.,

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

2. Steady state technology gap is increasing at the rate of entrepreneurial innovation, $\mu^e$, i.e.,

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

Proof. See Appendix A

The next 2 sections briefly discuss the derived properties.

2.8.1 Equilibrium under Perfect but Static Financial Markets

A message that naturally comes out of this model is that no matter how financially developed is an economy, as captured by a high value of $\lambda_t$, blocking innovation in the financial sector will eventually bring the economy to a halt as evident in Figure 2.

![Figure 2: Static Financial Markets](image)

Note that the effects of preventing innovation in a well functioning financial market may not become immediately evident in the rate at which entrepreneurial innovation takes place since a high initial $\lambda_t$ would in the short run allow for correctly identifying the potential entrepreneurs. Inevitably however, the absence of financial innovation is bound to become more pronounced both as the world technology frontier accelerates and the initial stock of financial expertise
becomes gradually obsolete. It is important to stress that this financially caused poverty trap is not an outcome of the presence of credit constraints it is rather a natural consequence of the financiers’ failure to keep up with an improving world technology.

In this case an increase at the rate of financial innovation in a non financially innovating economy will have a growth effect since it will allow for convergence to the world growth rate.

2.8.2 Equilibrium under Dynamic Financial Markets

As long as financial innovation within a country is positive this will allow for convergence to the world growth rate. In this case improvements in financial innovation will always have a level effect on country’s steady state technological gap. In this case it is important to remember that changes in factors affecting financial or entrepreneurial innovation will have a multiplier effect on the overall functioning of the economy.

![Dynamic Financial Markets](image)

3 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 Schum-
peterian 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.

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.
4 References

References


