What Does the Walrasian Auctioneer Know? Technology Adoption and Financial Innovation

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PRELIMINARY

Abstract

This paper proposes the view that financial development and economic growth are linked through the characteristics of technology. Perhaps the most obvious connection between technology and financial innovation emerges through risk-sharing. Technology is modeled as a distribution function over output values. While progress allows higher output values to be attained, it also changes the risk profile faced by economic agents. Technology adoption depends on the ability of the financial sector (the auctioneer) to price the new contingencies, therefore expanding the set of risk-sharing contracts offered to economic agents. The auctioneer is less knowledgeable about new technologies relative to entrepreneurs. As very high skilled entrepreneurs adopt the new technology, the auctioneer gradually learns how to price it. An implication of the analysis is the notion that financial development promotes economic growth only to the extent that it enhances the adoption of new technologies.

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1 Introduction

In most of the work addressing the relationship between economic progress and financial development, there is reference to the divide amongst well-known economists concerning the nature and importance of the relationship between those phenomena[1]. For example, in his *Theory of Economic History*, John Hicks [6] argues that the development of financial markets in England was a pivotal condition for the industrialization process started in 18th century England. Other classical references on the topic of growth and financial development include Joseph Schumpeter [12] and Joan Robinson [10]. While the views of the former are qualitatively similar to those of Hicks (finance spurs growth), Robinson argues that economic entrepreneurship leads to financial innovation.

This paper proposes the view that financial development and economic growth are linked through the characteristics of technology, as follows. Perhaps the most obvious connection between technology and financial innovation emerges through risk-sharing. Technology is modeled as a distribution function over output values. Technological progress occurs when Nature makes new distribution functions available to economic agents. In choosing which technology to operate, agents simultaneously select the risk profile of their income source. While progress allows higher output values to be attained, it also changes the risk profile faced by economic agents. The financial sector — here impersonated by the Walrasian auctioneer — provides risk intermediation among agents who face distinct risk profiles.

How does financial intermediation affect technology adoption and, as a consequence, growth? Financial innovation is understood here as the broadening of the set of contracts that are offered to agents as a means of risk intermediation. Technology adoption depends on the ability of the financial sector (the auctioneer) to price the new output contingencies, therefore expanding the set of risk-sharing contracts offered to economic agents. The auctioneer is less knowledgeable about new technologies relative to entrepreneurs. Specifically, he does not know how profitable new technologies are; he is also unable to tell how skilled a particular entrepreneur is relative to others in operating a new technology. If the skill level of the most able entrepreneurs is sufficiently high, they will adopt the new technology despite not being offered financial intermediation. Early adoption allows the auctioneer

[1] See Levine [9] for a survey.

to gradually learn about the profitability of the new technology and to identify the skill of those adopting it. By learning the features of the technology and restricting intermediation to the set of early adopters, the auctioneer is able to provide intermediation and avoid default in the financial system. In turn, as financial intermediation is made available as a consequence of learning, adoption is reinforced. An implication of the analysis is the notion that financial development promotes economic growth only to the extent that it enhances the adoption of new technologies.

A historical episode where the broadening of the set of financial contracts offered to economic agents enabled technology adoption is the British industrialization process. According to Hicks [6], the core feature of modern industry, born in England's Industrial Revolution, is the fact that fixed capital takes center stage and replaces circulating capital in the production process. In turn, financing fixed capital required the commitment of sizeable investments for long periods of time. Partly as a consequence of the Revolution of 1688, "that established Parliament as the key agency in managing national fiscal affairs,"[2] as well as the need to finance the British warfare, financial markets in England experienced significant developments, effectively becoming reliable providers of liquidity. There was a standardization of contractual details for government debt obligations, allowing for their uniform market pricing. "The new markets thrived because they provided liquidity for investment portfolios."[3] Capital markets, therefore, were able to match the liquidity needs of individual investors with the need for large scale financing of entrepreneurs. It was financial innovation that allowed for the implementation of new technologies, which, from a technological know-how standpoint, had already been available for some decades. The fact that technological knowledge had been available for some time but was not in use until financial markets provided adequate liquidity has been interpreted as evidence that technological innovation did not spark growth: technological development required an adequate financial infrastructure to be put in place before it could be incorporated into economic activity.

Another example of the relationship between the emergence of new financial arrangements and economic development was the establishment of trade in forward contracts, at the inception of the Chicago Board of Trade[4].

[2]Quotation from Baskin and Miranti [3].
[3]Idem.
[4]See Ferris [4].

Immediately after native Indians were forced to sell their ancestral lands, in 1833, Chicago experienced a burst of activity. Immigrants from the East moved to the region as soon as the ice broke in the Great Lakes. Many of the newcomers were New England and New York entrepreneurs who settled on fertile soils of northern Illinois and southern Wisconsin. By 1860, "the Old Northwest was the nation's granary made so by a mighty immigration from Europe and the eastern United States in the preceding decade."[5] The transportation of grain to the East was a process which depended on weather conditions. River merchants bought crop proceeds from entrepreneurs in the early Fall. Being able to ship the grain East required a not too cold Winter, so that the river would not freeze and shipments could sail away, and low humidity, in order not to damage the cereal. Often, as these two conditions failed them, river merchants ended up storing the grain all Winter. Transacting on forward contracts allowed these intermediaries to insure against the price variability between the time they purchased the grain, in the Fall, until the time of the final sale, by June of the following year.

This paper explores the relationship between financial innovation and technology adoption from the point of view of risk-sharing arrangements. There are other dimensions of technology that link financial arrangements to technology adoption. One example is asymmetric information. To the extent that technology forces shareholders to delegate on a manager the ability to run their firm given his greater expertise, contracts must be designed to convey adequate incentives to the manager. The literature on corporate finance addresses precisely the properties of such contracts. Yet another example is the presence of indivisibilities, discussed earlier in reference to the Industrial Revolution, as they require the matching of different patterns of liquidity requirements over time.

Going back to the initial debate concerning the direction of causality between finance and growth, the ideas presented here suggest that technological progress may require new contracts in order to materialize into economic activity. If this is the case, without such contracts, growth will not take place; but likewise, the arbitrary expansion of the set of financial contracts (financial innovation) without a technological demand for those contracts will not spur growth. The industrial revolution was an example where technological development had to wait for an adequate financial infrastructure that would support it. But such an infrastructure responded to specific technological

[5] Ferris [4].

needs that preceded financial innovation. River merchants in Chicago needed forward markets to insure against price risk. Had the Chicago Board of Trade not been created, this would have likely hampered the farming activity in the Midwest. But had the weather not been a factor in the transportation of grain during Winter, the Chicago Board of Trade would have witnessed no trade in forward contracts. The response of finance to the needs of technology seems to be perfectly summarized in Joan Robinson's [10] claim that "where enterprise leads finance follows." In the present context, enterprise is understood both as a new technology in a strict sense (that of scientific discovery), or as a new form of organizing one's business or conducting trade. The logical conclusion of the approach presented here is therefore that the positive correlation found empirically between financial development and growth (see King and Levine [7], Levine and Zervos [8], among many others) reflects an adequate response of the financial system to technological progress, but that there should be small gains from the implementation of an arbitrary financial reform, not targeted at specific technological needs.

2 Related Literature

This work relates most directly to Acemoglu and Zilibotti [1], Greenwood and Jovanovic [5], Bencivenga and Smith [2] and Saint-Paul [11]. Acemoglu and Zilibotti focus on conditions under which a more productive but riskier technology can be adopted and its implications for the volatility of output throughout the process of development. At early stages of development, the minimum size requirements of the risky project prevent its generalized adoption; as these projects bear idiosyncratic risk, the more projects adopted, the lower the aggregate risk for the economy. In their work, however, the set of technologies is fixed, and, conditional on the adoption decision, financial markets are complete. Similarly, in Greenwood and Jovanovic, the set of technologies is given and adoption depends on whether or not individual investors have become sufficiently wealthy to bear the fixed cost that financial intermediation entails. The current paper focuses on the rather different question of the implications of market incompleteness for technology adoption. Here, technology evolves exogenously and the adoption of more recent productive processes depends on the ability of the financial sector to provide new contracts that conform to the risk profile of the latest tier technology.

Bencivenga and Smith's work is centered around the comparative advantage of the financial system as a provider of liquidity to economic agents. In an economy with financial intermediation, individual needs to hold on to liquid but unproductive assets are reduced and the economy will grow faster as more funds are devoted to a more productive technology. Although the provision of liquidity to economic agents is one important dimension in which technology and financial innovation are related, as argued above, in this paper only the risk-sharing dimension of financial innovation is explored.

Saint-Paul has a model where productivity growth occurs through the specialization of labor. Firms determine their degree of specialization by selecting a particular technology from a given set. Higher specialization exposes the firm to greater (demand) uncertainty. Financial markets allow firms to insure against uncertainty, leading to a higher degree of specialization and, consequently, to greater productivity gains. This paper takes the opposite direction of Saint-Paul's approach. It asks the question of how the performance of financial markets will affect the adoption of exogenous technological progress.

3 The Model

There are two types of agents in the economy: savers and entrepreneurs. Savers own a perfectly safe technology which grants them a constant income y, $y > 0$; they are risk-neutral. Entrepreneurs, on the other hand, run a risky project and face endowment uncertainty; they are strictly risk-averse expected utility maximizers, with Bernoulli utility function $u(\cdot)$.[6] Both types of agents are infinitely lived and discount the future with discount factor $\beta \in (0, 1)$. The mass of entrepreneurs is the number n_e whereas n_s indicates that of savers.

Entrepreneurs operate a risky technology. Technologies are characterized by a probability density function (pdf) over output values (the positive real numbers). For simplicity, and without loss of generality, they will assume a very simple structure. Specifically, technologies will have two mass points and share a common probability profile over output realizations. Let the set $\mathcal{O}$ be defined as follows:

$$\mathcal{O} = \{(\theta_i, \theta_j) : \theta_i, \theta_j \in \mathbb{R}_+, \ \theta_i < \theta_j\}.$$

[6] The assumption of risk-neutrality for savers is made for simplicity; the results would be qualitatively similar if one considered risk-averse savers, instead, but risk-aversion would come at a substantial cost in terms of the tractability of the model.

Then, the set $\mathcal{F}$ of all technologies is the set of all probability density functions whose support is an element of $\mathcal{O}$, and where

$$prob\,(\theta_i) = q, \quad prob\,(\theta_j) = 1 - q, \quad \text{for } (\theta_i, \theta_j) \in \mathcal{O},$$

with $q \in (0, 1)$. While $\mathcal{F}$ contains all technologies that could possibly be operated, only a strict subset of $\mathcal{F}$ is known at a given moment in time. $\mathcal{F}_t$ denotes the technologies that entrepreneurs know how to operate in period t. As time passes, Nature may reveal new technologies to economic agents. It follows that $\mathcal{F}_{t+1} \supseteq \mathcal{F}_t$.

In this paper, we will consider the process of technology adoption as a new technology becomes available, and how such a process is affected by the nature and depth of financial intermediation. At the beginning of time, only f_1 is known: $\mathcal{F}_0 = \{f_1\}$. Technology f_1 has support over $\Theta_1 = \{\theta_1, \theta_3\}$. Later, in period $t > 0$, as a result of technological progress, f_2 becomes available: $\mathcal{F}_t = \{f_1, f_2\}$. Technology f_2 has support over $\Theta_2 = \{\theta_2, \theta_4\}$. In comparing the support of Θ_1 and Θ_2, the subindexes reflect an ordering in terms of magnitudes:

$$\theta_i > \theta_j \Longleftrightarrow i > j.$$

It is appropriate to think of f_1 as an earlier generation technology. The idea of technological progress suggests that newer technologies should allow higher output levels to be attained, and this is indeed the case when we compare f_2 with f_1. Technological progress need not be associated with first-order stochastic dominance, however, but as this assumption makes it more likely that entrepreneurs prefer f_2 relative to f_1, it makes the results sharper.

Contingencies in $\theta \in \mathcal{O}$ represent sector-wide shocks. That is, all entrepreneurs operating a given technology $f_l \in \mathcal{F}$ will face a common output draw (all receive θ_i, or else all experience θ_j, with $(\theta_i, \theta_j) \in \mathcal{O}$); there is no idiosyncratic risk in this economy.

Entrepreneurs are identical concerning their ability to run the old technology f_1. If they choose to operate f_1, their income will be θ_i, with probability q, and θ_j with probability $1 - q$.

Concerning f_2, entrepreneurs are characterized by a skill level $s_i \in S$, $S = [1, \bar{s}]$. The number s_i is the marginal product of individual i in the risky sector. Comparing individuals i and j for whom $s_i > s_j$, if both adopt f_2, output for individual i will be $s_i\theta_l$, for $\theta_l \in \Theta_2$, and only $s_j\theta_l$ for individual

j. Consequently, the expected value of operating f_2 is higher for person i. The distribution of skill over S is given by the pdf $g(\cdot)$.

Since savers and entrepreneurs experience different risk profiles, they could engage in mutually beneficial insurance arrangements. We assume that all risk intermediation has to be carried out through the financial system (here impersonated by the Walrasian auctioneer). For example, savers cannot approach entrepreneurs and offer to trade contingent claims directly. One justification for this restriction is the comparative advantage of the financial sector — in real world economies — in enforcing financial contracts, relative to private economic agents.

4 Equilibrium with One Technology

We start at time 0, when only f_1 is known by economic agents. We assume that the auctioneer is fully informed about the features of the technology (that is, he knows the support of f_1 and how productive entrepreneurs are in its operation).

The role of the financial sector is to intermediate risk between savers and entrepreneurs. The auctioneer simply announces a price vector $p(\theta)$ at which it promises to trade (buy or sell) contingent claims on the state of the world $\theta \in \Theta_1$. The behavior of the financial sector is then described by the function $p(\theta)$:

$$p : \Theta_1 \rightarrow \mathbb{R}_+.$$

The interpretation of $p(\theta)$ is the price at which the auctioneer promises to trade contingent claims on the state of the world θ. Although buying and selling prices could differ, we assume both a perfectly competitive financial system and the absence of intermediation costs. These two assumptions drive any intermediation margins to zero. After uncertainty is resolved, if θ materializes, the auctioneer will give one unit of the consumption good to an agent who bought one contingent claim on the state of the world θ, and will collect an identical amount from agents who hold short positions on the same contingency. The auctioneer will buy or sell any amount of claims from the agents at its posted price $p(\theta)$.

Let $c(\theta) = \{c_e(\theta), c_s(\theta)\}$ denote the consumption of entrepreneurs and savers when the state of the word is θ. Likewise, $a(\theta) \equiv \{a_e(\theta), a_s(\theta)\}$ represents the quantity of contingent claims bought by each type of agent as a function of θ.

Entrepreneurs and savers maximize utility taking the price vector $p(\theta)$ as given. When technology f_1 is used, individual entrepreneurs solve:

$$\max_{c_e(\theta)} \{qu(c_e(\theta_1)) + (1-q)\,u(c_e(\theta_3))\}$$

subject to:

$$\sum_{\theta\in\Theta_1} p(\theta)\,c_e(\theta) \leq \sum_{\theta\in\Theta_1} p(\theta)\,y_e(\theta).$$

Given $\theta \in \Theta_1$, the optimal amount of contingent claims $a_e(\theta)$ is given by the difference $c_e(\theta) - y_e(\theta)$. Savers solve an identical problem, but with the concave function $u(\cdot)$ replaced with linear utility.

We say that the market for securities clears if, given $p(\theta)$,

$$n_e a_e(\theta) + n_s a_s(\theta) = 0.$$

Definition 1 *An equilibrium in the economy where only f_1 is known is an allocation $\{c_e(\theta), c_s(\theta)\}$ and a price vector $p(\theta)$, $\theta \in \Theta_1$, such that: given the price vector $p(\theta)$, $c_e(\theta)$ maximizes the utility of entrepreneurs and $c_s(\theta)$ maximizes the utility of savers; the securities' market clears.*

Let μ_s denote the Lagrangian multiplier associated with the savers' resource constraint. First-order conditions for the savers include:

$$\begin{aligned} q &= \mu_s p(\theta_1) \\ (1-q) &= \mu_s p(\theta_3). \end{aligned}$$

These imply:

$$\frac{1-q}{q} = \frac{p(\theta_3)}{p(\theta_1)}. \tag{1}$$

As long as this condition holds, savers are indifferent as to how they split their income across the two assets.

We use the normalization $p(\theta_1) = 1$ and equation (1) to define:

$$p \equiv \frac{p(\theta_3)}{p(\theta_1)} = \frac{1-q}{q}.$$

Solving the problem of entrepreneurs, we assume for simplicity that their utility function is logarithmic. Consumption $c_e(\theta)$ is given by:

$$c_e(\theta_1) = q(\theta_1 + \theta_3 p), \qquad c_e(\theta_3) = (1-q)\left(\frac{\theta_1}{p} + \theta_3\right),$$

whereas the corresponding demand functions for Arrow securities are:

$$\begin{aligned} a_e(\theta_1) &= c_e(\theta_1) - \theta_1 = q\theta_3 p - (1-q)\theta_1 \\ a_e(\theta_3) &= c_e(\theta_3) - \theta_3 = (1-q)\frac{\theta_1}{p} - q\theta_3. \end{aligned}$$

Substituting in the price ratio for p, we get:

$$\begin{aligned} c_e(\theta_1) &= q\theta_1 + (1-q)\theta_3 = \bar{\theta}_1 \\ \\ c_e(\theta_3) &= q\theta_1 + (1-q)\theta_3 = \bar{\theta}_1, \end{aligned}$$

where $\bar{\theta}_1$ equals the expected income of entrepreneurs:

$$\bar{\theta}_1 = q\theta_1 + (1-q)\theta_3.$$

Since savers are risk neutral, we obtain a predictable outcome: entrepreneurs are fully insured against the variability of their income stream by the savers. Entrepreneurs have constant consumption in every period, a consumption stream corresponding to the expected value of their income process.

Finally, embedded in market clearing is the requirement that the equilibrium be feasible: the income y of savers must be enough to meet the entrepreneurs' insurance demand in any state of the world. Solving for the entrepreneurs' demand for Arrow secutiries, we get:

$$\begin{aligned} a_e(\theta_1) &= c_e(\theta_1) - \theta_1 = (\theta_3 - \theta_1)(1-q) > 0 \\ \\ a_e(\theta_3) &= c_e(\theta_3) - \theta_3 = q(\theta_1 - \theta_3) < 0. \end{aligned}$$

Feasibility will only be of concern in the bad state of the world for f_1 entrepreneurs (when θ_1 occurs). We need:

$$y \geq a_e(\theta_1)$$

or

$$y \geq (\theta_3 - \theta_1)(1-q). \tag{2}$$

We assume equation (2) is satisfied.

5 Technological Progress

We now go to period t, the period when Nature makes f_2 known to entrepreneurs: $\mathcal{F}_t = \{f_1, f_2\}$.

The financial intermediary is less knowledgeable about the new technology relative to entrepreneurs. Specifically, he faces uncertainty in two dimensions. The first one concerns the profitability of the new technology: the auctioneer does not know the support of f_2. Since all technologies have support in $\mathcal{O}$, however, he knows there are only two possible realizations of output and, further, their corresponding probabilities. Once f_2 is feasible, the set of states of relevant contingencies (states of the world) becomes

$$\Theta \equiv \{(\theta_1, \theta_2), (\theta_1, \theta_4), (\theta_3, \theta_2), (\theta_3, \theta_4)\}.$$

Although entrepreneurs know Θ, at t, the auctioneer only knows Θ_t:

$$\Theta_t = \{\{(\theta_1, \theta_i), (\theta_1, \theta_j)\}, \{(\theta_3, \theta_i), (\theta_3, \theta_j)\}\},$$

for $(\theta_i, \theta_j) \in \mathcal{O}$, $(\theta_i, \theta_j) \neq (\theta_1, \theta_3)$.

The second dimension in which the auctioneer is at a knowledge disadvantage is the ability of individual entrepreneurs to operate the new technology. He cannot tell apart the skill level of different entrepreneurs and he also ignores what the distribution of skill is (and, therefore, its support). These dimensions in which entrepreneurs are better informed relative to the auctioneer reflect two realistic features of the interaction between the financial system and entrepreneurs: as a new technology becomes available, the latter typically know more about its profitability. Further, information asymmetries and adverse selection concerning the talent and ability of individual entrepreneurs are well-known to affect the functioning of credit markets.

If some entrepreneurs undertake f_2, the auctioneer will be able to observe the output they generate. This will allow the auctioneer to learn about an individual's performance relative to others, as well as about the support associated with the new technology. If entrepreneur i undertakes f_2, the auctioneer will see total output, $s_i\theta_2$, if θ_2 occurs, or $s_i\theta_4$, should θ_4 take place instead. The auctioneer is further able to remember this information over time: once he observes $s_i\theta_j$, he will know, in all future periods, that individual i produces $s_i\theta_j$ when θ_j occurs. Therefore, if a group of entrepreneurs adopts f_2 before financial intermediation is provided, observation of the outcomes allows the auctioneer to learn about the relative skill of different individuals as well as to pin down the ratio θ_4/θ_2. For this ratio to be learned, the auctioneer needs to observe output draws for the *same* entrepreneur across different periods t and $t+j$, $j \geq 1$, corresponding to the two possible draws of θ; say, for example, that θ_2 occurs in t and θ_4 in $t+j$ (or the other way round).

We define the set A_{t+j}, $j \geq 0$, as follows.

$$A_{t+j} = \{i : s_i \text{ adopted } f_2 \text{ in } t+j\}.$$

That is, A_t is a record of the individuals who adopted the new technology in period $t+j$. Let

$$A^{t+j} \equiv \{A_t, A_{t+1}, \ldots, A_{t+j}\},$$

and $\sigma(A^{t+j})$ be the sigma-algebra of all the sets in A^{t+j}. We note that the group of individuals who adopted the technology at least once, up to and including period $t+j$, $j \geq 0$, $\cup_{l=0}^{j} A_{t+l}$, is in $\sigma(A^{t+j})$.

Since our goal is to explore the relationship between financial innovation and technology adoption, we assume that entrepreneurs can only buy insurance for the technology they operate. That is, say an entrepreneur adopts f_1; then, he will face the constraints:

$$a_e(\theta_1, \theta_2) = a_e(\theta_1, \theta_4), \quad a_e(\theta_3, \theta_2) = a_e(\theta_{3,}\theta_4).$$

In turn, these imply constant consumption across states where f_1 has identical realizations ($c_e(\theta_1, \theta_2) = c_e(\theta_1, \theta_4)$, for example). The auctioneer is therefore able to exclude individuals who adopt f_1 from purchasing amounts of contingent claims as a function of the realizations of f_2 and, likewise, he can exclude f_2 adopters from buying contingent claim amounts that vary as a function of f_1 realizations. A natural setting where this can be accomplished is the case when projects are verifiable: the auctioneer can see whether a particular entrepreneur is adopting f_1 or f_2 (building a factory can be distinguished from operating a small business). We say that intermediation over f_2 is available when, given $\theta \in \Theta_1$, the auctioneer posts prices $p(\theta, \theta_2)$ and $p(\theta, \theta_4)$ (and similarly for intermediation over f_1). Verifiable technology allows the auctioneer to remain intermediating over f_1 even before he has learned f_2.

Finally, it is assumed that there is a very high cost associated with default in the financial system. Should the auctioneer post prices and offer to intermediate over a set of contingencies and, given his lack of information, fail to deliver on the offered contracts, he will not be able to perform financial intermediation in any future period as a consequence of the distrust of economic agents concerning the financial sector. This assumption could be the outcome of a trigger strategy played by the agents: once default has occurred, agents will simply not participate in the market for financial claims. Its relevant consequence, for our purposes, is the timing it implies as to when financial intermediation over a new technology is first offered. Given that the auctioneer does not know the support of f_2 neither the distribution of skill over S, he will have to wait long enough to observe two different output realizations. If, as will be the case under some assumptions, a subset of entrepreneurs chooses to adopt f_2 before financial intermediation over this technology is available, then the auctioneer will have to wait at least two periods before he intermediates over f_2. Specifically, in the first period the technology is adopted, he will observe the distribution of $s_i\theta_j$, for entrepreneurs that adopt f_2; if next period's realization of θ is different from θ_j, the auctioneer learns the value of θ_4/θ_2. Therefore, from period $t+3$ onwards, the auctioneer knows both the ratio θ_4/θ_2 as well as the skill and corresponding density of entrepreneurs who previously adopted f_2. By restricting financial intermediation over f_2 to this group of entrepreneurs, the auctioneer will be able to prevent bankruptcy. Stated differently, since he knows the density of skill conditional on previous adoption, he knows the total demand for contingent claims for insurance over f_2 that he will face. He is also able to observe the demand for contingent claims associated with f_1 adoption. Bankruptcy is avoided by verifying that the certain income y of savers is enough to meet the demand for insurance from the different types of entrepreneurs under the 4 possible states of the world. Intermediation will have to be offered later (after $t+3$) if, however, the realization of θ is identical to that of the earlier draws, as the auctioneer does not learn the ratio θ_4/θ_2.

The necessity of restricting f_2 intermediation to entrepreneurs who have adopted in earlier periods has been justified by the auctioneer's ignorance of $g(\cdot)$; if intermediation is not conditional on previous adoption, it could be the case that the total amount of resources needed to insure f_2 entrepreneurs in the bad state of the world (θ, θ_2), for $\theta \in \Theta_1$, exceeded the total income y of savers.

While direct solvability is one relevant dimension of bankruptcy, it is perhaps not the most interesting one. Another interpretation for the need to condition intermediation on previous adoption is the problem of adverse selection. Given logarithmic utility, it is clear that, if the optimal choice of financial claims of an entrepreneur whose skill is s_i is $a(s_i) = \{a_e((\theta,\theta_2), s_i), a_e((\theta,\theta_4), s_i)\}$, the optimal choice of another entrepreneur with skill s_j, $s_j < s_i$, should equal $a(s_j) = \left\{\frac{s_j}{s_i} a_e((\theta,\theta_2), s_i), \frac{s_j}{s_i} a_e((\theta,\theta_4), s_i)\right\}$. However, provided he could default on insurance arrangements, the lower skill entrepreneur would like to contract the exact same amounts $a(s_i)$ that the higher skilled entrepreneur contracts. This is so since in the bad f_2 state θ_2, he will receive more insurance than by contracting $a(s_j)$ and, in the good states, he does not pay; in fact, given that $s_j < s_i$, the income generated by those whose skill is s_j may be too low to fulfil their financial obligations and pay $a_e((\theta,\theta_4), s_i)$ to the auctioneer.[7] Therefore, although this is not explicitly imposed on the auctioneer's design of financial contracts, the ability to exclude from intermediation those entrepreneurs whose skill has not yet been observed may be justified on the more interesting grounds of avoiding bankruptcy by guarding against adverse selection. We next formalize the possibility of restricting intermediation to a group of entrepreneurs.

Definition 2 *Let $\mathcal{A}$ be an element of $\sigma(A^{t+j-1})$. An intermediation rule for period $t+j$ is a function $I_{t+j} : \mathcal{A} \to \{0,1\}$.*

If, for all $i \in \mathcal{A}$, it is the case that $I_{t+j}(i) = 1$, all entrepreneurs whose name is in $\mathcal{A}$ (and who, therefore, must have adopted the technology at least once previous to period $t+j$) will be granted financial intermediation over f_2 in period $t+j$. The intermediation rule allows the auctioneer to restrict intermediation to a set of entrepreneurs who adopted f_2 in the past. We assume further that the intermediation rule is known by entrepreneurs.

We next define an equilibrium for this economy. Let

$$c^l_{e,s_i,t+j} : \Theta \times \mathcal{A}_{t+j-1} \to \mathbb{R}_+, \text{ with } \mathcal{A}_{t+j-1} \in \sigma\left(A^{t+j-1}\right).$$

That is, $c^l_{e,s_i,t+j}$ represents the consumption of an entrepreneur whose skill is s_i, whose adoption decision in period $t+j$ is to operate technology l, $l \in \{1,2\}$; consumption depends further on the period draw of θ, θ_{t+j}, and on the adoption history of the economy up to the previous period. Likewise, let

$$c_{s,t+j} : \Theta_{t+j} \times \mathcal{A}_{t+j-1} \to \mathbb{R}_+, \text{ with } \mathcal{A}_{t+j-1} \in \sigma\left(A^{t+j-1}\right).$$

be the savers' consumption in period $t+j$.

[7] We have implicitly assumed, so far, that there is perfect enforceability of financial contracts so that agents never default on their financial claims.

Let $\tau_{i,t+j}$ denote the technology adoption decision of entrepreneur with skill s_i in period $t+j$. We assume:

$$\tau_{i,t+j} : \Theta_{t+j-1} \rightarrow \{1, 2\}.$$

When $\tau_{i,t+j} = l$, the entrepreneur whose skill is s_i chose to adopt f_l in $t+j$. The adoption decisions are functions of the auctioneer's knowledge of the technology.

The timing is as follows. After Nature draws the new technology f_2 in period t, the auctioneer posts a price sequence $\{p_{t+j}(\theta_{t+j})\}_{j=0}^{\infty}$, where $p_{t+j} : \Theta_{t+j} \rightarrow \mathbb{R}_+$ and $j \geq 0$, and a sequence of intermediation rules, $\{I_{t+j}\}_{j=0}^{\infty}$. In every period after and including t, entrepreneurs decide which technology to adopt and, if granted intermediation, contract a vector of financial claims with the auctioneer. Output is realized as a function of chance and the entrepreneurs adoption decisions; the total output of individual entrepreneurs is observed by the auctioneer and so are the adoption decisions. The auctioneer services the financial contracts agreed upon at the beginning of the period. The information set of the auctioneer Θ_{t+j} is updated according to the output realizations of period $t+j$, and $\sigma(A^{t+j})$ is also updated. Then:

Definition 3 *An equilibrium in the economy where entrepreneurs know f_1 and f_2 is a consumption allocation $\left\{c^1_{e,s_i,t+j}, c^2_{e,s_i,t+j}, c_{s,t+j}\right\}_{j=0}^{\infty}$, a sequence of prices $\{p_{t+j}(\theta_{t+j})\}_{j=0}^{\infty}$, where $p_{t+j} : \Theta_{t+j} \rightarrow \mathbb{R}_+$, a sequence of adoption decisions $\{\tau_{i,t+j}\}_{j=0}^{\infty}$, for each entrepreneur i, with $s_i \in S$, and a sequence of intermediation rules $\{I_{t+j}\}_{j=0}^{\infty}$ such that: given the sequences of prices and intermediation rules, the adoption decisions and consumption allocation maximize the expected discounted utility of each type of entrepreneur; given the sequences of prices and intermediation rules, $c_{s,t}$ maximizes the savers' utility; the market for securities clears.*

Definition 4 *A steady-state is an equilibrium where $c^1_{e,s_i,t+j} = c^1_{e,s_i}$, $c^2_{e,s_i,t+j} = c^2_{e,s_i}$, $c_{s,t+j} = c_s$, $\forall j \geq 0$, and where adoption decisions of individual entrepreneurs and the intermediation rule remain constant over time.*

In the next sections, we characterize the equilibria leading up to and including the steady-state.

5.1 Adoption Dynamics

For adoption decisions to be made, forward looking entrepreneurs will take into account the path of prices over time. The absence of intermediation costs and perfect competition in the market for financial claims imply that, as soon as the new technology is learned, intermediation will be offered. Market clearing requires that the relative prices charged by the auctioneer over pairs of contingencies be the corresponding relative probabilities; otherwise, the linearity of the savers' utility function will lead them to buy or sell short infinite amounts of claims over particular contingencies. Bankruptcy prevention further implies the need to restrict intermediation to entrepreneurs whose skill and density are already known. Competition in the financial market implies that, once f_2 is learned, the set of entrepreneurs to whom intermediation is offered in period $t+j$ will correspond to $\cup_{l=t}^{t+j} A_l$. The intermediation rule, therefore, provides insurance to the largest possible set of previous adopters.

Once an entrepreneur is granted intermediation over f_2, from risk-aversion, he will choose to fully insure. Consequently, once intermediation over f_2 becomes available, the consumption of entrepreneurs adopting f_2 will equal $\bar{\theta}_2 \equiv q\theta_2 + (1-q)\,\theta_4$ forever. Just as before, entrepreneurs always consume the expected output of the technology they adopt.

We guess, and later verify, that adoption is a process reinforced by time. First, only very high skilled entrepreneurs adopt the new technology. As time passes and the auctioneer learns more about f_2, less skilled entrepreneurs decide to adopt, even previous to intermediation being offered, as the expect time left to intermediation is decreasing. Finally, once the technology is learned by the auctioneer, a final group of entrepreneurs will adopt f_2. In addition, all of those who had previously adopted the new technology are reinforced in their decision: the expected discounted utility from continuing to adopt f_2 exceeds that of switching back to f_1 even if intermediation over this technology were to be remain operative.

The reinforcement effect of time over adoption implies the following adoption criterion. In deciding whether or not to switch to f_2, entrepreneurs compute the expected discounted utility from operating f_2 forever with the expected utility from using f_1 also for the entire future.

First-Period Adoption. We analyze the adoption decision at t, the first period f_2 is known by entrepreneurs. As mentioned earlier, the auctioneer needs to wait at least two periods before he can offer intermediation. This is so since he needs to observe the two different draws of θ, $\theta \in \Theta_2$.[8] The probability that intermediation is offered in the third period after Nature draws f_2 (in $t+3$), is therefore $q(1-q)+(1-q)q$, or $2q(1-q)$. With the complementary probability, $q^2+(1-q)^2$, the auctioneer was only able to observe the same realization of θ in the previous periods and will not intermediate in period $t+3$. Intermediation will not be available in period $t+4$ with probability $q^3+(1-q)^3$, and so on. Forward looking entrepreneurs will adopt the technology at t if their skill level s is such that:

$$\left((1+\beta)+\beta^2\left(q^2+(1-q)^2\right)+\beta^3\left(q^3+(1-q)^3\right)+\ldots\right)\left(q\ln\left(s\theta_2\right)+(1-q)\ln\left(s\theta_4\right)\right)$$
$$+\left(\beta^2\left(1-\left(q^2+(1-q)^2\right)\right)+\beta^3\left(1-\left(q^3+(1-q)^3\right)\right)+\ldots\right)\ln\left(s\bar{\theta}_2\right)\geq\frac{1}{1-\beta}\ln\left(\bar{\theta}_1\right)$$

or

$$\underbrace{\left((1+\beta)+\frac{\beta^2q^2}{1-\beta q}+\frac{\beta^2(1-q)^2}{1-\beta(1-q)}\right)}_{\equiv a_0}\left(q\ln\left(s\theta_2\right)+(1-q)\ln\left(s\theta_4\right)\right) \qquad (3)$$
$$+\underbrace{\beta^2\frac{(2-\beta)\,q\,(1-q)}{(1-\beta)(1-\beta q)(1-\beta(1-q))}}_{\equiv b_0}\ln\left(s\bar{\theta}_2\right)\geq\frac{1}{1-\beta}\ln\left(\bar{\theta}_1\right).$$

The first parcel in equation (3) reflects the expected utility associated with operating the new technology without intermediation. The greater the coefficient a_0, reflecting the probability of not being granted intermediation, the greater the cost from switching to f_2. The second term on the left-hand side is the expected utility associated with intermediation. The greater b_0, the greater the benefit from operating f_2. The expected benefit from operating f_2 must exceed the cost for technology adoption to be undertaken. Clearly, the left-hand side of (3) is increasing in s: only the most able entrepreneurs will adopt the technology when it first becomes available. Let s_0 denote the skill level such that (3) is satisfied with equality. For technology adoption to be undertaken, it must be the case that $s_0<\bar{s}$. We assume $s_0\in(1,\bar{s})$ below, while analyzing the dynamics of technology adoption. We discuss this assumption in section 5.2

[8] In fact, he does not observe θ directly, only the distribution of $s_i\theta$, for those entrepreneurs i that adopt f_2. But knowledge of θ_4/θ_2 is sufficient for intermediation to be offered.

In period t, therefore, the mass of entrepreneurs adopting f_2, n_0, is

$$n_0 = \int_{s_0}^{\bar{s}} g(s)\, ds.$$

Entrepreneurs whose skill is smaller than s_0 choose to stick to f_1. Consumption of the latter is the same as before, $q\theta_1 + (1-q)\theta_3$. Since those who adopt f_2 are not able to insure away the variability of their income, they simply consume the proceeds of their risky project: $s_i\theta_j$, for $j = 2, 4$.

Feasibility requires that the savers' income be enough to meet the demand for insurance of f_1 adopters. Stated differently, this condition requires that the savers' consumption be positive in all states of the world. From market clearing in consumption, we have:

$$\begin{aligned} c_s(\theta_1) + (1-n_0)\, c_e^1(\theta_1) &= (1-n_0)\,\theta_1 + y \Longleftrightarrow \\ c_s(\theta_1) &= (1-n_0)(1-q)(\theta_1 - \theta_3) + y. \end{aligned}$$

We therefore need $c_s(\theta_1) > 0$, which is already implied by the problem solved in section 4 (where a similar condition was assumed under $n_0 = 0$).

Second-Period Adoption. The passing of time allows the auctioneer to learn. At $t+1$, we have a more knowledgeable auctioneer since he has been able to observe the output draws associated with one value of θ. Therefore, it must be the case that the expected costs associated with using the old technology are now lower while, for precisely the same reason, the expected benefits from using the new one and benefitting from intermediation must be higher. If this is so, less skilled entrepreneurs (relative to those whose skill is at least s_0) will now find it beneficial to start operating f_2, while those who previously adopted are reinforced in their choice of technology.

Suppose θ_2 occurred in period t, an event with probability q. Then, in period $t+1$, all entrepreneurs whose skill s is such that:

$$\begin{gathered} \left(1 + \beta q + \beta^2 q^2 + \ldots\right)\left(q \ln(s\theta_2) + (1-q)\ln(s\theta_4)\right) \\ + \left(\beta(1-q) + \beta^2\left(1-q^2\right) + \beta^3\left(1-q^3\right) + \ldots\right)\ln\left(s\bar{\theta}_2\right) \geq \frac{1}{1-\beta}\ln\left(\bar{\theta}_1\right) \end{gathered}$$

or

$$\underbrace{\frac{1}{1-\beta q}}_{\equiv a_1(\theta_2)}\left(q\ln(s\theta_2) + (1-q)\ln(s\theta_4)\right) + \underbrace{\frac{\beta(1-q)}{(1-\beta)(1-\beta q)}}_{\equiv b_1(\theta_2)}\ln\left(s\bar{\theta}_2\right) \geq \frac{1}{1-\beta}\ln\left(\bar{\theta}_1\right), \tag{4}$$

will adopt f_2. Let $s_1(\theta_2)$ denote the value of s for which the previous equation is satisfied with equality. Simple algebra shows that $a_1(\theta_2)$ is smaller than a_0: the learning experienced by the auctioneer reduces the expected cost associated with the lack of intermediation. Conversely, $b_1(\theta_2)$ exceeds b_0: learning raises the expected benefits from f_2 adoption associated with intermediation. Further, $b_1(\theta_2) - b_0 = -(a_1(\theta_2) - a_0)$. Since $\ln\left(s\bar{\theta}_2\right) > q\ln(s\theta_2) + (1-q)\ln(s\theta_4)$, the left-hand side of (4) is greater than that of (3). The value of $s_1(\theta_2)$ for which (4) holds with equality must therefore be strictly smaller than s_0: $s_1(\theta_2) < s_0$. As a consequence of learning, adoption is a more generalized process in period $t+1$ than when it was first available.

The implications of learning are qualitatively identical should θ_4 have been observed in $t+1$: $s_1(\theta_4) < s_0$, and less able entrepreneurs adopt f_2 since the cost of waiting has been reduced.

For $\theta \in \Theta_2$, the mass of adopters, $n_1(\theta)$, is now:

$$n_1(\theta) = \int_{s_1(\theta)}^{\bar{s}} g(s)\, ds.$$

As before, entrepreneurs whose skill is below $s_1(\theta)$ consume $\bar{\theta}_1$. Adopters consume $s_i\theta_j$, $j = 2, 4$. The income of savers remains sufficient to supply the f_1 adopters' demand for insurance.

It could be the case that $s_1(\theta) \leq 1$, for some $\theta \in \Theta_2$. This would mean that all entrepreneurs would switch to f_2 in the period after f_2 became available. Below, we assume this is not the case and, in fact, additional dynamics take place before the steady-state.

Transition and Steady-State. Since the realizations of θ are independent over time, conditional on the realization in period t, $\theta_t \in \Theta_2$, the expected waiting time and corresponding utility cost from adoption remain unchanged in future periods (provided the ratio θ_4/θ_2 still has not been learned). This implies that no further adoption will take place until the period after θ_4/θ_2 is learned. Suppose that θ_2 was observed in t and has been repeatedly observed until $t+j$, $j > 1$, when θ_4 is observed instead. Then, there will be adoption in $t+1$, as a consequence of the fact that θ_2 was learned in t, but no more entrepreneurs will adopt the technology until period $t+j+1$. The set of entrepreneurs operating f_2 between periods $t+1$ and $t+j$ remains constant and corresponds to the set of individuals whose skill exceeds $s_1(\theta_2)$, with mass $n_1(\theta_2)$. Consumption of both types of entrepreneurs and of savers is identical to that described under second-period adoption.

Once θ_4 is learned, entrepreneurs with skill $s_1(\theta)$ or greater immediately receive consumption equal to their expected income, $q\theta_2+(1-q)\theta_4$. As a consequence of the technology having been learned, however, more entrepreneurs will join as the waiting time before they are granted financial intermediation becomes reduced to one period.

Entrepreneurs whose skill s exceeds s^* will operate f_2 from period $t+j+1$ onwards:

$$(q\ln(s^*\theta_2)+(1-q)\ln(s^*\theta_4))+\frac{\beta}{1-\beta}\ln\left(s^*\bar{\theta}_2\right)=\frac{1}{1-\beta}\ln\left(\bar{\theta}_1\right).$$

The skill level s^* characterizes the dividing skill level that separates f_1 adopters from f_2 adopters in the steady-state. As before, it is also the case that $s^*<s_1(\theta_j)$, $j=1,2$. In the steady-state, therefore, the mass n^* of f_2 adopters is

$$n^*=\int_{s^*}^{\bar{s}}g(s)\,ds.$$

Note, however, that the steady-state is only reached in period $t+j+2$. Although the steady-state mass of adopters is the same in $t+j+2$ and the previous period, the mass of adopters who choose to adopt in $t+j+1$ (the number $n^*-n_1(\theta)$) will only start receiving a constant flow of consumption starting in $t+j+2$.

We only have to check the feasibility of the steady-state equilibrium. It is sufficient to verify that the consumption of savers remains positive when both f_1 and f_2 adopters suffer bad shocks. From market clearing:

$$\begin{gathered}(1-n^*)\,c_e^1(\theta_1,\theta_2)+n^*c_e^2(\theta_1,\theta_2)+c_s(\theta_1,\theta_2)=y+(1-n^*)\,\theta_1+n^*\theta_2\Longleftrightarrow\\ c_s(\theta_1,\theta_2)=y+(1-q)(\theta_1-\theta_3)+n^*(1-q)(\theta_2-\theta_4).\end{gathered}$$

Feasibility requires:

$$\begin{gathered}c_s(\theta_1,\theta_2)\geq 0\Longleftrightarrow\\ y+(1-n^*)(1-q)(\theta_1-\theta_3)+n^*(1-q)(\theta_2-\theta_4)\geq 0,\end{gathered}$$

which we assume.

5.2 Discussion

Having characterized the adoption path, we now examine the results. It is useful to start by making the following assumption:

Condition 5 *The highest skill level $\bar{s}$ is such that*

$$\frac{\ln \bar{s}}{1-\beta} < \frac{\frac{1}{1-\beta} \ln\left(\bar{\theta}_1\right)}{\frac{1}{1-\beta}\left(q \ln \theta_2 + (1-q) \ln \theta_4\right)}.$$

The right-hand side of condition 5 is the ratio between the discounted utility from operating f_1 forever, under financial intermediation, and the expected discounted utility from operating f_2 without it. This condition says that, if the financial system were known to never provide financial intermediation over f_2, while providing intermediation over f_1 for the entire future, the new technology would not be adopted, not even by the most skilled entrepreneurs. Despite the first-order stochastic dominance of f_2 over f_1, the increment in utility from insurance made possible under f_1 outweighs the higher expected income that f_2 would provide, since operating the new technology would have to be made without insurance arrangements.

In this paper, given that the analysis has focussed on the insurance aspect of financial arrangements and its implications for technology adoption, condition 5 illustrates the crucial trade-off experienced by entrepreneurs. Adoption of f_2 will require losing the insurance benefits from operating a technology with which the financial system is well acquainted in order to gain higher expected income but without insurance smoothing. Condition 5 can be understood as an extreme version of (3), the equation defining the minimum skill level required to trigger f_2 adoption in period t, the first period entrepreneurs learn how to operate it. In (3), entrepreneurs take into account the positive probability of being offered intermediation after period $t+2$. This positive probability and its discounted value to t are collected in the coefficient a_0. The greater a_0, the greater the cost from the lack of insurance which early adopters need to endure. Conversely, the probability of being granted intermediation in the future (also discounted to t), is reflected in b_0. Relative to (5), it is as if, in that condition, we had set a_0 to unity and b_0 to zero. Given that, in the model, provided there is early adoption the probability of future intermediation is positive, the skill threshold s_0 required of the first adopters is smaller than the right-hand side of the one in condition (5). Nonetheless, given that the financial system learns from observing the performance of the early adopters, adoption still requires that there be sufficiently high skilled individuals to trigger the learning process.

Other important aspects of the model concern the way technology and the auctioneer's knowledge have been modeled. While the assumption of technologies characterized by two mass points is rather innocuous and its simplicity helpful in solving the model, the assumption that f_2 and f_1 are independent obscures potentially important implications of the learning speed of the auctioneer. Specifically, if f_1 and f_2 had been assumed to be correlated, knowledge of the correlation coefficient ρ by the auctioneer would allow him to learn the support of f_2 (and the skill density of early adopters) from the very first observation of θ, $\theta \in \Theta_2$. As a consequence, provided new technologies bear some correlation with old ones, there will be a greater mass of entrepreneurs who engage in early adoption (the cost from lack of insurance is reduced, making the skill threshold required for adoption lower) and financial intermediation will be offered within a shorter interval than before. Intuition suggests that the positive relationship between the intensity of early adoption and the speed at which the financial system starts intermediating, with the correlation coefficient between old and new technologies should generalize to more complex technologies and environments. This is an empirically testable implication.

The risk-neutrality of savers was crucial in simplifying the problem and allowing for the analytical computation of the equilibria along the adoption path to the steady-state. Specifically, it delivered the equivalence between relative prices and the ratio of probabilities across states and, more importantly, the invariability of prices throughout the adoption path (prices only changed once the technology was learned and, even then, the new prices were again straightforward to compute). Allowing for risk-averse utility would complicate the analysis dramatically in that the prices along the transition path would depend on the mass of the early adopters, which, in turn, would be changing over time. It is doubtful, however, that any additional insight would be granted by generalizing the analysis to risk-averse savers.

Financial innovation has been modeled here as the expansion of the set of contracts offered to economic agents in response to a change in the structure of uncertainty caused by technological progress. Two issues are of extreme importance. The first one is the chronology of events: the enlargement of the set of contingencies over which financial intermediation is performed, from Θ_1 to $\Theta = \Theta_1 \times \Theta_2$, *follows* technological progress. The set of states of the world and associated risk profile of the economy change as a consequence of technological changes. Financial innovation responds to technological news (provided early adoption in turn facilitates learning). The second aspect is the impact of financial innovation on economic growth in general. According to the model, financial deepening reinforces adoption but only to the extent that it conforms to the characteristics of the more recent technologies, and therefore meets the new insurance needs of entrepreneurs. These two implications of the model, in turn, suggest two testable propositions. One is that scientific progress (for example as measured by the number of registered patents in a given period) should *cause* financial innovation. The other, that arbitrary financial reform — not targeted at specific technological needs — should not have an impact on economic growth.

Finally, and to reinstate an interpretation matter stressed in the introduction, although this paper has dealt with the insurance aspects of technological progress, the relationship between financial innovation and technology adoption must be understood as broadly applying to all the features defining the implementation of new technologies. Other important such dimensions are private information and indivisibilities. To the extent that agency problems are associated with the implementation of new technologies, the financial system's response should, once again, be one of broadening the set of contracts offered to economic agents, allowing for the information-constrained implementation of the new technology. The same applies to indivisibilities, where the financial system ought to respond by finding adequate instruments to match the different liquidity needs of agents over time.

6 Conclusion

This paper proposed a novel link between financial innovation and growth through technology adoption. The properties of technology (risk-profile, indivisibilities, private information) determine an optimal set of contracts that allow economic agents to share the surplus associated with its implementation. The financial sector has an important role in making the adoption of new technologies possible by enlarging the set of financial contracts offered to the public as a response to the characteristics of new technologies.

Only the link between risk-sharing and technology adoption has been explored here. Technologies are interpreted as probability distributions over sets of outcomes. The Walrasian auctioneer intermediates the trade of contingent claims over states of the world across agents experiencing different risk-profiles. Technological progress is represented by a new probability distribution over outcomes, one that allows for higher income realizations but that simultaneously changes the risk-profile over output realizations. The decision to adopt a better technology was shown to depend on whether or not the financial sector expands the set of contingent claims it offers economic agents.

The current work is to be interpreted as a first step in what seems to be an area of research with very broad implications. Specifically, the ideas presented here suggest that financial arrangements serve as a support for economic activity and that there would be little or no gain from an arbitrary financial reform, not targeted at the specific requirements of technology.

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