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FINANCIAL INNOVATION AND RISK: THE ROLE OF INFORMATION

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Abstract

Financial innovation has increased opportunities for diversification and lowered investment costs, but has not reduced the relative cost of active (informed) investment strategies compared with passive (less informed) strategies. What are the consequences? I have studied an economy with linear production technologies, some more risky than others. Investors can use low quality public information or collect high quality, but costly, private information. Information helps in avoiding excessively risky investments. Financial innovation lowers the incentives for private information collection and causes a deterioration in public information: the economy more often invests in excessively risky technologies. This changes the properties of the business cycle and can reduce welfare by increasing the likelihood of "liquidation crises".

JEL Classification: G14, G33, G01, E32.
Keywords: financial innovation, information collection, great moderation, liquidation crisis.

Contents

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1 Introduction

Financial innovation is "exemplified by new derivative contracts, new corporate securities, new forms of pooled investment products, [...] or by new means of distributing securities and processing transactions" (Tufano [2002]). Indeed, in the last two decades, the US have witnessed a tremendous increase in the types of securities available to investors and a decrease in the cost of holding and trading them. Traditionally, economists have viewed the process of financial innovation as beneficial for two sets of reasons. First of all it spurs growth, thanks to the greater easiness with which funds flow from agents with low productive projects towards agents with high productive projects (Levine [1997], Rajan and Zingales [1998], Azariadis and Kass [2003], among others). Second, the amount of risk that investors bear is reduced, as a consequence of the availability of a broader menu of assets, allowing greater diversification and risk sharing (Merton [1987], Mendoza et al. [2008]). This traditional view has recently come under attack, particularly on the part where it predicates that financial development leads to risk reductions for investors. Indeed, some authors wonder whether financial development has made the world riskier and subject to "excessive risk taking" (Rajan [2005]), while others plainly state, with respect to securitization, that its "positive role [...] in dispersing risk" is an "old view, now discredited" (Shin [2009]).

This paper intends to contribute to the ongoing debate by highlighting the role of costly information collection as a channel, largely neglected by the literature, through which financial innovation shapes the amount and types of risk that investors choose to hold, the characteristics of aggregate economic fluctuations and, finally, welfare. Using data provided by French [2008] I find evidence that, for the US stock market, financial innovation was not accompanied by a reduction in the relative cost of active (i.e. more informed) trading compared to the cost of passive (less informed) trading. What are the possible consequences of this phenomenon? To answer this question I develop a theoretical model where agents learn about the quality of investment opportunities by choosing either to be active investors and acquire costly private information or to be passive and rely on less costly, but less precise, public information. Information is valuable because it avoids making low quality investments, which are investments in excessively risky technologies. Following the literature on noisy trading (Grossman and Stiglitz [1980], Kyle [1985], Summers and Shleifer [1990]) the overall amount of private information collected by active investors determines a positive externality on the precision of the public information. Under various assumptions on assets returns, I show that financial innovation leads to a decrease in the amount on private information collection whenever it is not accompanied by a reduction in the cost of investing actively relative to the cost of investing passively. The reason is that information is a

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strategic substitute to risk diversification. Financial innovation has positive welfare effects because it provides "insurance" to investors, by allowing them to trade a larger set of assets and thus to better diversify risk. However, as in a standard moral hazard problem, greater insurance reduces incentives to take costly actions, such as collecting private information, to avoid excessively risky investments. This theoretical finding is supported by a growing body of literature (Cremers and Petajisto [2009], French[2008]) that shows how US stock market holdings have consistently shifted form active to passive forms of investment in the past 20 years. Information collection affects welfare and the business cycle properties. The lower amount of private information collected, working through the externality of public information, has a negative impact on the welfare of passive investors, thus partly counterbalancing their gains from better risk sharing. With lower information, agents more often mistakenly invest in technologies characterized by excessive systemic risk: I derive business cycles statistics which incorporate the effects of information collection on the volatility and sensitivity to systemic shocks of the aggregate productivity. With this respect, the model adds a new theoretical perspective to the literature on the great moderation (Stock and Watson [2002], Fogli and Perri [2006], Dynan et al. [2006], Stiroh [2009]).
Finally I show how, in a more dynamic setting with time varying risk, information cycles arise. Financial development tends to reduce information collection in periods where excess risk is mainly idiosyncratic (and thus "insurable" through better diversification), but has no impact on information collection in periods when excess risk is mainly systemic. Consequently, financial development increases the frequency of "liquidation crises". These are situations when too risky investments are mistakenly undertaken in periods of idiosyncratic excess risk, only to be suddenly liquidated when excess risk becomes systemic and information collection soars. If liquidation crises impose aggregate costs to the economy, then financial development reduces welfare.

The remaining of the paper proceeds as follows. Section 2 reviews the empirical evidence, Section 3 presents technologies, preferences, information revelation mechanism and the equilibrium for the basic model. Section 4 extends the basic model to time varying risk and analyzes liquidation crises. Section 5 concludes.

2 Empirical evidence

To substantiate our discussion, it is worthwhile to review a few points about financial innovation. To this end, the US is an interesting reference country for which we have quite abundant empirical evidence. The three facts that I emphasize are the following: *a)* there has been a tremendous increase in the menu of assets and in diversification possibilities available to investors *b)* liquidity and trading costs have trended downwards since the '60s, but *c)* the cost of active investment strategies has not decreased *relative* to the cost of passive strategies. Point *a)* is easily illustrated with some examples. High-yield bond issuances went from about $50 billions in 1993, when issuances were entirely in the US, to

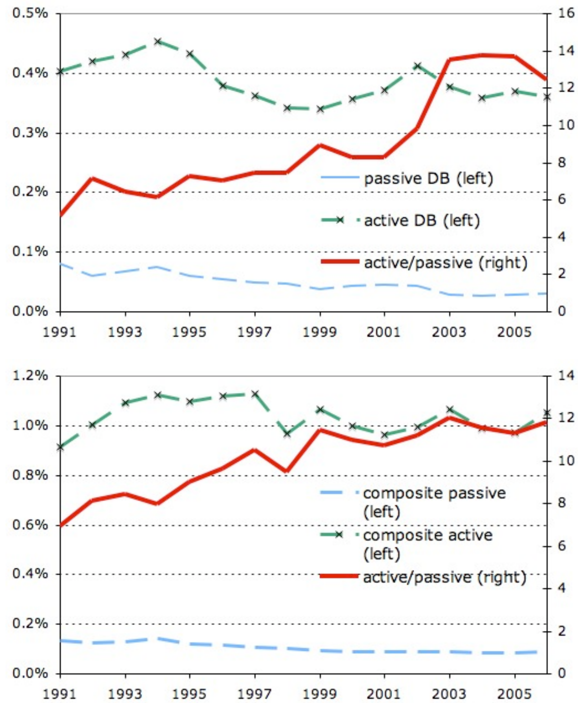

Figure 1: Cost of active and passive investment strategies (in % of investment) and relative cost of active strategies. Active and passive Defined Benefit pension funds (top). Composite active and passive strategies (bottom). The data used are from French (2008). Details on strategy construction are in Appendix E.

\$180 billions in 2006, with the US share going down to 70% (BIS [2008]). During the same period, the value of worldwide buyouts transactions undertaken by private equity funds went from a scanty \$30 billions to more than \$800 billions (Kaplan and Strömberg [2009]). The US market for asset-backed securities, that in 1998 was worth \$271 billion, increased four times in only a few years and reached over \$1,200 billions in 2006 (Weaver [2008]). Securitization in the US mortgage market, virtually absent two decades ago, reached 80.5% of mortgages originated in 2006, for a total value of \$2.4 trillions (Gorton [2008]). For the purpose of our discussion, the most important conclusion to be drawn is that the successful introduction of these new financial instruments (high-yield bonds, private equity, mortgage backed securities) opened up to investors new opportunities in markets (for high risk firms, unlisted companies, housing) that before had more limited access to external financing, mostly provided by very specialized investors (e.g. banks). A number of studies (for instance Jones [2002], French [2008]) confirm *b)* by establishing that trading costs in the stock market have decreased over time due to reductions in both bid-ask spreads and in trading fees. Things become more complicated when we want to investigate *c)*, since it requires the difficult task of ranking investment strategies by their "information content" and then of calculating the corresponding cost. The most comprehensive attempt to estimate information costs has been done by French (2008), who reports cost series for various investment strategies in the US stock market. Using these data, I analyze two alternative cost measures for active and passive investments. The first is the cost of active and passive Defined Benefit pension plans, while the second is the cost of composite active and passive strategies comprising investments in mutual funds, pension funds, hedge funds and direct equity holding. Figure 1 presents the two cost measures, and Appendix E provides more details on their construction. The common message is the following: the *absolute* cost of passive strategies has been trending downwards over time, while the *absolute* cost of active strategies has decreased to a much lesser extent. Consequently, the *relative* cost of active strategies has significantly increased over time, roughly doubling in the period 1991-2006. Certainly, a more precise measure of information costs would take into consideration the possibility that active strategies might have become much better in producing information. Measuring information costs using this sort of quality-adjusted index could indeed reveal that active investment strategies have not become, relative to passive strategies, as costly as Figure 1 suggests. Nonetheless, as a first order approximation, it seems reasonable to argue that quality considerations would not be so strong as to invert the clear trend in Figure 1.

The next section presents the basic model relating information collection to financial innovation. The model will allow us to highlight the consequences for the agents' risk taking behavior, for the business cycle and for welfare of a financial innovation process characterized by *a)-b)* and *c)*.

3 The basic model

3.1 Technologies and information structure

The economy lasts two periods $t = 1, 2$ and is endowed with $2N$ linear production technologies that use consumption goods at $t = 1$ as input and produce consumption goods at $t = 2$ as output. Technologies are evenly distributed distributed across N markets $m = 1, ..., N$, so that each market is associated with exactly two technologies $j = 1, 2$. Each technology is uniquely identified by a pair (m, j). In every market m, one technology is *low risk* and the other *excess risk*. The return on the excess risk technology in m is a mean preserving spread of the return on the low risk technology in m. The realization of a random type $\theta_m \in \{1, 2\}$ decides that technology $j = \theta_m$ is the excess risk technology in m (and thus $j = 3 - \theta_m$ is the low risk technology in m). Call $\Theta = (\theta_1, ..., \theta_N)$ the vector of types and $T = \{1, 2\}^N$ the set of such vectors. Call $r_{m,j}$ the return between $t = 1$ and $t = 2$ of

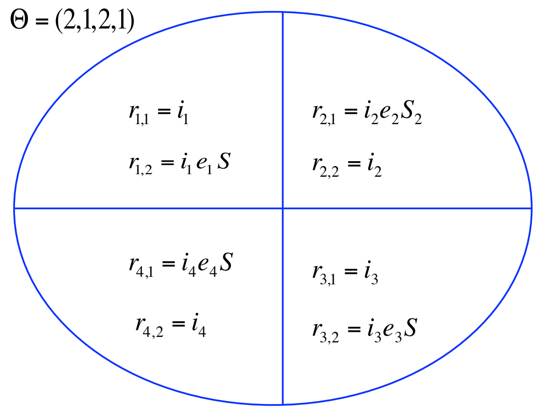

Figure 2: Economy divided in $N = 4$ markets. Within each market there are two linear technologies $j = 1, 2$ with random productivity $r_{m,j}$. The realized type is $\Theta = (2, 1, 2, 1)$ so technology $j = 2$ has excess risk in markets $1, 3$ and $j = 1$ has excess risk in markets $2, 4$.

technology (m, j) and assume that

$$r_{m,3-\theta_m} = i_m \tag{1}$$

$$r_{m,\theta_m} = i_m e_m S \tag{2}$$

The random variables i_m and e_m are i.i.d. across markets, while S is the systemic shock common to all markets. All shocks are independent of each other. I normalize to unity the expected returns by assuming that $E[i^m] = E[e^m] = E[S] = 1$ and I denote with σ_i^2, σ_e^2, σ_S^2 the variances of the shocks.

Figure 2 gives a graphical representation of markets and technologies. The setup is open to various interpretations. For instance, markets can represent different products, or different groups of customers segmented by geographical area, wealth or income. For every market, some choices of the production and marketing technologies are more risky than others. For example, a certain production technology may rely too much on inputs whose prices are very volatile, or a certain marketing strategy may target customers whose payment ability is very uncertain. Excess risk is modeled as a mean preserving spread over the low risk technology, in fact

$$r_{m,\theta_m} = r_{m,3-\theta_m} + z_m$$

where the excess risk $z_m = i_m(e_m S - 1)$ satisfies

$$E[z_m | r_{m,3-\theta_m}] = 0$$

Given a realization of $r_{m,3-\theta_m}$ the source of excess risk in z_m is twofold: excess idiosyncratic risk e_m and excess systemic risk[1] S.

The joint distribution of types is summarized by a probability function $F(\Theta)$ that satisfies a symmetry condition

$$F(\Theta) = F(\theta_1, ..., \theta_N) = F(3 - \theta_1, ..., 3 - \theta_N) = F(\bar{\Theta}) \tag{3}$$

for every $\Theta \in T$. Condition (3) simply requires that the probability of realization of a type Θ equals the probability of realization of its *opposite type* $\bar{\Theta}$ defined as $\bar{\Theta} = 3 - \Theta$. The *ad hoc* assumption (3) greatly simplifies our calculations but is not very restrictive, since it encompasses a wide range of behaviors for the joint distribution of types. For instance, consider the case of perfect positive correlation among market types θ_m. Here the support of $F(\cdot)$ is the pair of vectors $\Theta_1 = (1, ..., 1)$ and $\Theta_2 = (2, ..., 2)$. Assumption (3) then simply requires that $F(\Theta_1) = F(\Theta_2) = \frac{1}{2}$. To the other extreme, the case of i.i.d. types automatically satisfies (3), since $F(\Theta) = \frac{1}{2^N}$ for any $\Theta \in T$.

We are ready to describe the information structure of the economy, i.e. the way in which information about the realization of Θ flows to the agents in the economy. For now, we conveniently assume that the information structure is exogenously imposed to the economy, but in Section 3.4 I will derive in detail the microeconomic mechanism that allows this structure to emerge as an equilibrium outcome of the model.
First of all, at the beginning of time 1 all agents are informed that the current realization of types satisfies $\Theta \in T_\Theta$ where

$$T_\Theta \equiv \Theta \cup \bar{\Theta} \tag{4}$$

In other words, after the types are realized the only initial uncertainty for agents is whether the realized type is the true Θ or its opposite. Notice that, conditional on this information, assumption (3) implies that the two types are equally likely. Next, agents have two ways to further refine their knowledge. The first is to become an *active* investor, a choice that reduces the investor's wealth to a fraction[2] $1/\xi^A$ of its original value, with $\xi_A > 1$, and allows the observation of a private signal $I^A(\Theta)$ such that

$$I^A(\Theta) = \Theta \tag{5}$$

Alternatively, an investor can choose to be *passive*. Passive investors face investment costs that reduce their wealth to a fraction $1/\xi_P$, with $1 < \xi_P < \xi_A$, but observe a public signal $I^P(\Theta)$,

$$I^P(\Theta) = I^\rho \Theta \tag{6}$$

[1]To reduce notation, I normalize to zero the amount of systemic risk in the diversifiable technology technologies. This has no qualitative effect on the results. A case with systemic risk also in the low risk technology is presented in Section 4.

[2]This gives rise to a constant return to scale for information collection. For a analysis of increasing returns technologies see Van Nieuwerburgh and Veldkamp (2008).

where I^ρ is a binary random variable, independent on Θ, which equals 1 with probability $\rho \in [0,1]$ and zero otherwise. Active investors are able to take fully informed investment decisions, but have to pay a high cost. Instead, passive investors pay a smaller cost but can rely only on the public signal I^P, which is less precise. In fact, I^P is informative if and only if $I^\rho = 1$, an event realized with probability ρ, while if $I^\rho = 0$ the public signal is uninformative and the types Θ and $\bar{\Theta}$ remain perfectly confounded. The precision of the public information is summarized by the *revelation rate* ρ. More formally, signal observation refines an agent's believe about the true realization of the types. In particular, an agent who observes a signal $I \in \{\mathbf{0}, \Theta\}$ learns that $\Theta \in T_{\Theta,I}$ where

$$T_{\Theta,I} = \begin{cases} \Theta & \text{for } I = \Theta \\ T_\Theta & \text{for } I = \mathbf{0} \end{cases} \tag{7}$$

Define $\eta \in [0,1]$ the fraction of active investors at time 1. To make public information a positive spillover of private information collection I assume that

$$\rho = A^E \eta \tag{8}$$

for $A^E \in (0,1)$. As mentioned above, the initial observability (4), the particular binary choices for the public signal $I^P \in \{\mathbf{0}, \Theta\}$ and the form of the spillover function (8) are all derived from first principles in Section 3.4.

All agent have to pay a cost to access investment opportunities, but active agents, who have superior information, face higher costs. For this reason, we can identify with $\xi > 1$ the *relative information cost*, where

$$\xi = \frac{\xi^A}{\xi^P}$$

In terms of points *b)* and *c)* in Section 2, financial innovation appears to be associated with in costs ξ_A and ξ_P, but not with a decrease in ξ. The remaining point *a)*, relating financial innovation to greater diversification opportunities, can be modeled in the following way. Assume that each investor draws a *specialization* h in market $h = 1, ..., N$. Call p_h the fraction of investors with specialization h. Agents are constrained to invest at most a fraction $1 - \bar{\alpha}$ of their portfolio outside their market of specialization, where $\bar{\alpha} \in \left[\frac{1}{N}, 1\right]$ is the *barrier to diversification*.

The degree of financial development of an economy is summarized by the vector of *distortions* $D = (\xi_A, \xi_P, \bar{\alpha})$. As financial innovation decreases D, investment costs are reduced and diversification possibilities improve. As a word of caution, it is worthy to emphasize that the separate treatment of the barriers $\bar{\alpha}$ and of the investment costs ξ_A, ξ_P is a convenient artifact but should not be taken too literarily. These variables are all rooted in the same types of market imperfections that financial innovation, when beneficial, helps to eradicate. For instance, high barriers $\bar{\alpha}$ may be due the presence of asymmetric information and moral hazard preventing investors to venture in unfamiliar markets, thus forcing them to concentrate their wealth in a few markets; lack of a centralized financial market

for a certain class of assets raises liquidity costs and reduces the number of investors who trade in those assets; explicit regulatory requirements can restrict the possibility to trade some types of assets. These same imperfections are also the cause of high investment costs ξ_A, ξ_B, which must be interpreted in a broad sense as to include all "the cost of transmitting information from one party to another" (Merton [1987]). Examples are costly contracting schemes needed, in the framework of a principal-agent problem, to implement a truthful communication and reduce moral hazard (Holmström and Milgrom [1987], Townsend [1979], Benmelech et al. [2009]).
Finally, it is important to stress that the focus of the paper is not on developing a theory of endogenous emergence of financial innovation, the distortions D are in fact treated as exogenous to the economy.

3.2 Preferences

Agents' preferences are given by an homothetic utility function, which allows a parametric separation between risk aversion and intertemporal elasticity of substitution. Call $\{c_{t,I}\}$ any consumption process for time $t = 1, 2$ chosen by the agent after observing a signal $I \in \{\mathbf{0}, \Theta\}$ at the beginning of time 1. Conditional on I, consumption $c_{1,I}$ is deterministic, but consumption $c_{2,I}$ is stochastic, since it depends on the random return at $t = 2$ of the agent's investement. A conditional consumption process yields a value V_I given by

$$V_I = \left\{ c_{1,I}^{1-\frac{1}{\psi}} + \beta \left[E(c_{2,I}^{1-\gamma}) \right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}}$$

for $\beta \in [0, 1]$. The ex-ante utility U to the agent is the following,

$$U = \left[EV_I^{1-\gamma} \right]^{\frac{1}{1-\gamma}} \tag{9}$$

Similarly to Epstein and Zin (1989), the utility function disentangles the relative risk aversion coefficient $\gamma > 0$, $\gamma \neq 1$ from the elasticity of intertemporal substitution $\psi > 0$, $\psi \neq 1$. As we will see, this choice is made to allows a better interpretations of the results. Notice also that by setting $\gamma = \frac{1}{\psi}$ the usual CRRA utility is obtained.

3.3 The problem of the investor

At time $t = 1$, an investor first chooses whether to be active ($\tau = A$) or passive ($\tau = P$), then observes the corresponding signal I^τ, and finally makes investment decisions. Investment choices are given by a saving rate x and a portfolio share $\alpha_{m,j}$ for every technology (m, j) in the economy, subject to the barrier to diversification $\bar{\alpha}$. Therefore, given an exogenous realization of Θ, an investor endowed with initial unit wealth and specialization h solves

$$\max_\tau EV_I^{1-\gamma}(\tau, h)$$

where,

$$V_I(\tau, h) = \max_{x, \{\alpha^h_{m,j}\}} \left\{ c_{1,I}^{1-\frac{1}{\psi}} + \beta \left[E c_2^{1-\gamma}(\Theta) | \Theta \in T_{\Theta,I} \right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}} \tag{10}$$

$$\begin{aligned} \text{s.t.} \quad & c_{1,I} = (1 - x_I)/\xi_\tau \\ & c_2(\Theta) = \hat{r}^h(\Theta) x_I/\xi_\tau \\ & \hat{r}^h(\Theta) = \sum_{(m,j)} \alpha^h_{m,j} r_{m,j}(\Theta) \\ & \alpha^h_{1,h} + \alpha^h_{2,h} \geq \bar{\alpha} \\ & \sum_{(m,j)} \alpha^h_{m,j} = 1 \end{aligned}$$

Refinements (7) imply that for agents with an informative signal $I = \Theta$ uncertainty about the portfolio return $\hat{r}^h$ stems only from uncertainty on the realization of the productivity shocks i, e, S. Agents with an uninformative signal $I = \mathbf{0}$, instead, face further uncertainty about the types realization. The solution for the optimal portfolio shares is quite intuitive[3]. Call $\alpha^{h*}_{m,j}(I)$ the optimal portfolio shares of an investor specialized in h when she observes a signal I. When $I = \Theta$ the investor is informed about the true type and avoids investing in excess risk technologies. Moreover, since the returns of low risk technologies are i.i.d. across markets, the best strategy to minimize the remaining risk is to distribute the total investment as evenly as possible across markets, conditional on the barrier $\bar{\alpha} \geq 1/N$. Therefore,

$$\begin{array}{ll} \alpha^{h*}_{m,\theta_m}(\Theta) = 0 & \forall m \\ \alpha^{h*}_{h,3-\theta_h}(\Theta) = \bar{\alpha} & \\ \alpha^{h*}_{m,3-\theta_m}(\Theta) = \frac{1-\bar{\alpha}}{N-1} & m \neq h \end{array} \tag{11}$$

When $I = \mathbf{0}$ the signal is uninformative and, from the point of view of the investor, returns on all technologies are identically distributed. Therefore, to minimize risk, the investment is spread as evenly as possible across technologies, which implies that a share $\bar{\alpha}/2$ is assigned to each of the two technologies in market h and the remaining share $1 - \bar{\alpha}$ is equally distributed across the other $2(N - 1)$ technologies,

$$\begin{array}{ll} \alpha^{h*}_{h,j}(\mathbf{0}) = \frac{\bar{\alpha}}{2} & j = 1, 2 \\ \alpha^{h*}_{m,j}(\mathbf{0}) = \frac{1-\bar{\alpha}}{2(N-1)} & m \neq h, j = 1, 2 \end{array} \tag{12}$$

[3]For a detailed derivation see Appendix A

Substituting for the optimal portfolio shares, we conclude that, for a given Θ, the portfolio return $\hat{r}_I^h$ of an investor with information I and specialization h is

$$\hat{r}_\Theta^h = \bar{\alpha} i_h + \sum_{m \neq h} i_m$$

$$\hat{r}_0^h = \frac{\bar{\alpha}}{2}(i_h + i_h e_h S) + \frac{1-\bar{\alpha}}{2(N-1)} \sum_{m \neq h} (i_m + i_m e_m S)$$

Notice that $\hat{r}_I^h$ is independent on Θ. Clearly, an informed investor holds a less risky portfolio than that of an uninformed investor, in fact

$$r_0^h = r_\Theta^h + \varepsilon^h$$

where

$$\varepsilon^h = \frac{\bar{\alpha}}{2} i_h (e_h S - 1) + \frac{1-\bar{\alpha}}{2(N-1)} \sum_{m \neq h} i_m (e_m S - 1)$$

and $E[\varepsilon^h | r_\Theta^h] = 0$. For a realization Θ, call R_I the risk-adjusted return to the portfolio of an investor with information I and specialization h,

$$R_I = [E(\hat{r}_I^h)^{1-\gamma}]^{\frac{1}{1-\gamma}} \tag{13}$$

Risk adjusted returns are independent both on h and on the particular realization Θ. Since $\hat{r}_0^h$ is a mean preserving spread of r_Θ^h, a simple application of Jensen's inequality gives

$$R_0 < R_\Theta$$

Using the results obtained so far and the homotheticity of the utility function, the optimal saving rates are found by rewriting $V_I(\tau, h) = \frac{1}{\xi_\tau} \hat{V}_I$ where

$$\hat{V}_I = \max_x \left\{ (1-x)^{1-\frac{1}{\psi}} + \beta x^{1-\frac{1}{\psi}} R_I^{1-\frac{1}{\psi}} \right\}^{\frac{1}{1-\frac{1}{\psi}}} \tag{14}$$

For every signal I, the first order conditions of the problem give the optimal saving rate x_I^*,

$$x_I^* = \frac{1}{1 + \beta^{-\psi} R_I^{1-\psi}} \tag{15}$$

Since all agents, informed or uninformed, allocate a fraction $\bar{\alpha}$ of their investment into their own market of specialization and a fraction $\frac{1-\bar{\alpha}}{N-1}$ to each of the other markets, we can derive aggregate *market shares* ω_m, representing the fraction of aggregate investment devoted by the economy to market m,

$$\omega_m = \bar{\alpha} p_m + \frac{1-\bar{\alpha}}{N-1}(1 - p_m)$$

For instance, when financial development is at its minimum $\bar{\alpha} = 1$, only the fraction p_m of agents with specialization in m invest in m, and thus $\omega_m = p_m$. From a diversification perspective, some markets will receive too little capital and others too much. Instead, when financial development is at its maximum $\bar{\alpha} = 1/N$ investors can perfectly diversify their portfolio beyond their original specialization, and thus $\omega_m = 1/N$ for all m.

3.4 The microfundation of the information structure

When collection of information is costly markets cannot be informationally efficient (Grossman and Stiglitz [1980]), otherwise the superior information available to active investors would be costlessly revealed to passive investors by investment choices, which are publicly observable. However, if the precision of the public information is reduced by the presence of an aggregate noise, then costly collection of private information can still be valuable. This idea is formalized by assuming that passive investors observe the investments made by active investors plus a noise. The noise can be interpreted as created by mistakes in investment choices or in its measurement, or by the activity of another class of agents, the liquidity investors, whose portfolio decision is influenced by random factors, such as liquidity needs.

Assume that there is a constant amount $\bar{L}$ of noisy investment in the economy, distributed across markets according to the market shares ω_m. A random variable | with support $[0, \bar{L}]$ determines the total amount of noisy investment which is directed towards excess risk technologies. Call $y(m, j)$ the sum of active and noisy investment made in technology (m, j). We then have,

$$\begin{aligned} y(m, \theta_m) &= \omega_m L \\ y(m, 3-\theta_m) &= \frac{\omega_m}{\xi_A} x^*_\Theta \eta + \omega_m(\bar{L} - L) \end{aligned}$$

where as usual η is the fraction of investors active in each market. Each active investor has a net wealth $1/\xi_A$ and a saving rate x^*_Θ. The quantity $\frac{\omega_m}{\xi_A} x^*_\Theta \eta$ is then the overall amount of active investment directed to the low risk technology in market m. Call $\mathbf{y} = (y(1,1), y(1,2), ..., y(N,1), y(N,2))$ and assume that $\bar{L} < x^*_\Theta/\xi_A$. Passive investors use the Bayes rule to deduce the realization of the types from the observation of $\mathbf{y}$. Fix a reference market m and, for $j = 1, 2$, define

$$L_j = \frac{y(m, j)}{\omega_m}$$

The value L_j corresponds to the realization of the noise L consistent with a observation $y(m, j)$ and a realized type $\theta_m = j$ in our reference market m. For $j = 1, 2$ define $\Theta_j \in T_\Theta$ the vector of types consistent with a realization $\theta_m = j$ in our reference market m. Appendix B shows that if (3) holds then,

$$\text{Prob}\{\Theta_j | \mathbf{y}\} = \frac{u(L_j)}{u(L_j) + u(L_{3-j})} \tag{16}$$

where $u(\cdot)$ is the probability density function of L. First of all, notice that $\text{Prob}\{\Theta_1|\mathbf{y}\} + \text{Prob}\{\Theta_2|\mathbf{y}\} = 1$ and this is consistent with our initial assumption (4) that agents are always informed about $T_\Theta = \{\Theta, \bar{\Theta}\}$. Equation (16) generates the structure (6) for the public signal if, for instance, L is uniformly distributed on $[0, \bar{L}]$, as the following example shows. Assume that θ_m is the true realization of the type in the reference market m, so that $\Theta = \Theta_{\theta_m}$ is the true realization of the vector of types. If there is a low realization $L < \frac{\eta}{\xi_A} x^*_\Theta$ then it is easy to verify that $L_{3-\theta_m} > \bar{L}$. Therefore $u(L_{\theta_m}) = 1/\bar{L}$, $u(L_{3-\theta_m}) = 0$. Then $\text{Prob}\{\Theta_{\theta_m}|\mathbf{y}\} = 1$ and $\text{Prob}\{\Theta_{3-\theta_m}|\mathbf{y}\} = 0$. Suppose instead that the realization of the noise is sufficiently large, $L \geq \frac{\eta}{\xi_A} x^*_\Theta$. Then $L_{3-\theta_m} \leq \bar{L}$, $u(L_{\theta_m}) = u(L_{3-\theta_m}) = 1/\bar{L}$ and hence $\text{Prob}\{\Theta_{\theta_m}|\mathbf{y}\} = \text{Prob}\{\Theta_{3-\theta_m}|\mathbf{y}\} = \frac{1}{2}$. In conclusion, if $L < \frac{\mu}{\xi_A} x^*_\Theta$ types are revealed to passive agents by the low level of investment in the excess risk technologies, while if the noise is sufficiently large the true type $\Theta = \Theta_{\theta_m}$ is undistinguishable from $\bar{\Theta} = \Theta_{3-\theta_m}$. Notice that the revelation rate is

$$\rho = \text{Prob}\left\{L < \frac{\eta x^*_\Theta}{\xi_A}\right\} = \frac{\eta x^*_\Theta}{\bar{L}\xi_A}$$

The externality function (8) is obtained by setting

$$A^E = \frac{x^*_\Theta}{\bar{L}\xi_A}$$

3.5 Equilibrium

In an equilibrium where the revelation rate is strictly positive the fraction of active investors is also strictly positive. In this situation, the equilibrium revelation rate ρ^* makes indifferent the marginal investor between being active or passive, that is

$$\frac{1}{\xi_A^{1-\gamma}} \hat{V}_\Theta^{1-\gamma} = \frac{1}{\xi_P^{1-\gamma}} [\rho^* \hat{V}_\Theta^{1-\gamma} + (1-\rho^*) \hat{V}_0^{1-\gamma}]$$

where the left hand side is the utility (9) from being active and the right hand side is the expected utility from being passive. Solving we obtain

$$\rho^* = 1 - \frac{\xi^{\gamma-1} - 1}{\left(\frac{\hat{V}_\Theta}{\hat{V}_0}\right)^{\gamma-1} - 1} \tag{17}$$

An internal solution $\rho^* \in (0, 1)$ is obtained whenever

$$\left(\frac{\hat{V}_\Theta}{\hat{V}_0}\right)^{\gamma-1} > \xi^{\gamma-1}$$

Definition 1. *An equilibrium is given by*

1. *investment policies x_I^* that solve (15), and portfolio policies $\alpha_{m,j}^{h*}(I)$ satisfying (11), (12), given ρ^*.*

2. *a revelation rate ρ^* equal to the maximum between zero and the value (17), and a fraction η^* of active investors satisfying (8).*

We have then the following Proposition.

Proposition 1. *There exists one and only one equilibrium. Values $\hat{V}_I$ are given by*

$$\hat{V}_I = \left(\beta^\psi R_I^{\psi-1} + 1\right)^{\frac{1}{\psi-1}} \tag{18}$$

for $I \in \{\mathbf{0}, \Theta\}$. For interior solutions, the revelation rate is

$$\rho^* = 1 - \frac{\xi^{\gamma-1} - 1}{\left(\frac{\beta^\psi R_\Theta^{\psi-1}+1}{\beta^\psi R_0^{\psi-1}+1}\right)^{\frac{\gamma-1}{\psi-1}} - 1} \tag{19}$$

Proof. Substitute (15) into (14) to obtain (18), which is then substituted into (17) to get (19). □

The equilibrium revelation rate is ultimately a function of the exogenous vector of distortions D, so we write $\rho^*(D)$. Since ρ^* equalizes the value of being active and passive the revelation rate turns out to be, not surprisingly, a function of the relative information cost ξ and not of ξ_A and ξ_B separately. We can perform comparative statics exercises to see how financial innovation affects ρ^* through reductions in the distortions D. In particular, to mimic the stylized facts suggested in Section 2, I consider exogenous reductions in ξ_A, ξ_B and $\bar{\alpha}$ leaving ξ unchanged. I restrict my attention to two interesting cases that help us give a clear interpretation of the forces behind the relation $\rho^*(D)$. The first case is obtained by setting $i_m = 1$, so that the low risk technology is risk free and excess risk is both idiosyncratic e_m and systemic S. In the second, I set $e_m = 1$ so that all technologies have an idiosyncratic component i_m and the excess risk is only systemic S. I will also focus on interior equilibria $\rho^* > 0$.

Proposition 2. *Consider changes in D that leave ξ unchanged. Then,*

i) If $i_m = 1$ a.s. then $\rho^*(D)$ is a strictly increasing function.

ii) If $e_m = 1$ a.s. then $\rho^*(D)$ is strictly increasing for $\psi < 1$ and strictly decreasing for $\psi > 1$.

Welfare strictly decreases in the distorsions D.

Proposition 2 show that information collection decreases whenever financial innovation favors mostly passive investors relative to active investors. To explain this point it is useful to analyze the ratios $\zeta_x = x_\Theta / x_0$ and $\zeta_R = R_\Theta / R_0$ representing, respectively, the saving rate and risk adjusted return of an informed investor relative to those of an uninformed investor. In case *i)* informed investors face no risk at all since $R_\Theta = 1$, while passive investors face idiosyncratic and system risk. Financial development decreases the relative return ζ_R of informed investors by boosting only the return R_0 of uninformed investors, who can better diversify the excess risk they hold. Since active investors are always informed while passive investors are sometimes uninformed, financial development favors passive investors relatively more than active investors. In case *ii)* we have $\zeta_R = \Omega^{-1}$ where

$$\Omega = \left(ES^{1-\gamma}\right)^{\frac{1}{1-\gamma}} < 1$$

The excess risk held by uninformed investors is all systemic, hence the relative return ζ_R is unaffected by the degree of diversification. In this case, therefore, the channel that allows D to affect ρ^* is not simply the change in ζ_R, but is the behavior of the relative saving rate ζ_x. When the elasticity of intertemporal substitution is smaller than one $\zeta_x < 1$, because the share of individual wealth consumed by informed investors, who face a higher return R_Θ, is bigger than that of the uninformed investors, who save relatively more to compensate for their lower return R_0. Therefore, even though financial innovation doesn't change ζ_R, it still favors more uninformed investors (and thus passive investors) who are the ones that are more exposed to investment risk and then reap overall greater fruits from the improvement in diversification possibilities. The opposite i true when $\psi > 1$, but this latter case seems much less relevant for macroeconomics, where both the econometric (Hall [1988]) and the quantitative (Kydland and Prescott [1982]) literature traditionally consider values of ψ smaller than 0.5. For $e_m = 1$, the elasticity ψ determines the direction (decrease/increase) in which ρ^* changes in response to a decrease in D, while the relative risk aversion γ influences the size of such change. In fact, substituting $\zeta_R = \Omega^{-1}$ into (19) we obtain

$$\rho'^*_{1-\bar{\alpha}} \equiv \frac{\partial \rho^*}{\partial(1-\bar{\alpha})} = g(R_\Theta, \Omega) \frac{\partial R_\Theta}{\partial(1-\bar{\alpha})}(1 - \Omega^{\psi-1})$$

where $g(R_\Theta, \Omega)$ is a strictly positive function. Risk adjusted returns increase with diversification[4], so $\frac{\partial R_\Theta}{\partial(1-\bar{\alpha})} > 0$ for any value of the parameters. The elasticity ψ determines the sign of $\rho'^*_{1-\bar{\alpha}}$ while, for given R_Θ and Ω, $\frac{\partial R_\Theta}{\partial(1-\bar{\alpha})} > 0$ influences its absolute value. The higher the risk aversion, the larger is $\frac{\partial R_\Theta}{\partial(1-\bar{\alpha})}$, since the greater is the positive diversification effect on R_Θ generated by a small reduction in the distortion $\bar{\alpha}$. For instance as γ approaches zero investors become risk neutral and $R_\Theta = 1$ for any $\bar{\alpha}$, so that $\frac{\partial R_\Theta}{\partial(1-\bar{\alpha})} = 0$. These different roles for ψ and γ cannot be uncovered in the standard formulation $\gamma = \frac{1}{\psi}$.

[4]Appendix A proves this point formally.

Having established that financial innovation tends to decrease information, it is interesting to assess how this affects aggregate welfare and the business cycle. For equilibria with interior ρ^*, investors' welfare is simply given by the welfare of active investors $\hat{V}_\Theta/\xi_A$. Welfare gains from financial innovation come from lower costs ξ_A and from a lower barrier $\bar{\alpha}$ to diversification, which allows R_Θ in (18) to increase. However, these net positive welfare gains can be greatly reduced by a decrease in the amount of information ρ^*. The starkest example is provided by case *a)*, where a decrease in $\bar{\alpha}$ does not change $\hat{V}_\Theta$. It follows that if we keep ξ_A and ξ_B constant, welfare is unaffected by a strict decrease in the barrier $\bar{\alpha}$. But how is it possible that higher diversification does not rise the welfare of passive investors, who are likely to be uninformed and thus to face excess idiosyncratic risk? The answer is that, in this case, the positive effect of a lower $\bar{\alpha}$ is exactly offset by an endogenous decrease in the quality ρ^* of public information. The mechanism is that of a typical moral hazard problem, working through the information externality (8). As diversification possibilities increase, investors become "more insured" against excess risk and thus, ceteris paribus, find it less valuable to take the costly action of collecting private information to eliminate the chance of facing such risk. In other words, information collection and diversification are strategic substitutes for investors. The lower collection of private information reduces the quality ρ^* of the public signal, and this impacts negatively on the welfare of passive investors, exaclty counterbalancing the positive effect of a low $\bar{\alpha}$.

Lower public information means that more investors (lower η^*) invest more often (lower ρ^*) in the "wrong technologies", i.e. in technologies with excess risk. This result is important and suggests that the finding of Proposition 1 regarding the positive welfare value of financial innovation could be quite fragile. Indeed, in Section 4 I extend the basic framework to a more dynamic setting in which risk is time varying and where periods when excess risk is mainly idiosyncratic are followed by periods when excess risk becomes systemic. I show that financial development increases the probability of "liquidation crises", i.e. situations in which investments in excess risk technologies, initially mistakenly undertaken by uninformed investors, are suddenly liquidated when the increase in systemic risk triggers a wave of information collection. If liquidation crises impose aggregate costs to the economy, then financial innovation can reduce welfare.

To present in simple ways the effect of financial innovation on the business cycle, I characterize the equilibrium values of the statistics σ_A^2 and $\gamma_{A,S} = \mathrm{Cov}(A,S)/\sigma_S^2$ giving, respectively, the volatility of the multifactor productivity A and the regression parameter measuring the sensitivity of the productivity to systemic shocks. The productivity A is defined as

$$A(\Theta, I^P) = \frac{\sum_h [\eta^* x_\Theta^* \hat{r}_\Theta^h + (1-\eta^*)\xi x_{I^P}^* \hat{r}_{I^P}^h] p_h}{\eta^* x_\Theta^* + (1-\eta^*)\xi x_{I^P}^*} \tag{20}$$

The multifactor productivity is the overall output at time 2 of the production technologies divided by time 1 total investment, and is expressed in (20) as the weighted average of the investors' portfolio return divided by total investment. Define Σ^2 the volatility of the excess risk technologies minus the volatility of i and S, and define $\hat{\sigma}^2_m$ the dispersion of the market shares ω_m,

$$\Sigma^2 = \mathrm{Var}(r_{m,\theta_m}) - \sigma_S^2 - \sigma_i^2$$
$$\hat{\sigma}^2_\omega = \sum_m \omega_m^2$$

Appendix C shows that when total noise $\bar{L}$ is small[5] the business cycle statistics are given by

$$\begin{aligned}\sigma_A^2 =& \hat{\sigma}^2_\omega \sigma_i^2 + \frac{1}{4}(\sigma_S^2 + \hat{\sigma}^2_\omega \Sigma^2)(1-\rho^*) + O(\bar{L}) \\ \gamma_{A,S} =& \frac{1}{2}(1-\rho^*) + O(\bar{L})\end{aligned} \tag{21}$$

Financial innovation, accompanied by a reduction in ρ^*, has ambiguous effects on aggregate volatility σ_A^2. It is a simple exercise[6] to show that a lower barrier to diversification $\bar{\alpha}$ always reduces the dispersion $\hat{\sigma}^2_\omega$ of market sizes and thus lowers σ_A^2. Dispersion of market shares $\hat{\sigma}^2_\omega$ amplifies the effects of idiosyncratic volatility since it allows idiosyncratic shocks to markets with above average share ω_m to affect aggregate volatility σ_A^2. This amplification operates both on the volatility of shocks i, and to the excess idiosyncratic volatility Σ^2 generated when, with probability $1-\rho^*$, the public signal is uninformative and passive investor allocate half of their portfolio to excess risk technologies. In the limit of perfect diversification ($\bar{\alpha} = 1/N$) and of a large number of markets ($N = \infty$), $\hat{\sigma}^2_\omega = 0$ because idiosyncratic volatility is washed away in the aggregate. In this case only the systemic volatility σ_S^2 remains and is amplified by reductions in ρ^*.
Clear-cut results are obtained for the sensitivity $\gamma_{A,S}$ which always increases in $1-\bar{\alpha}$. In fact, the smaller revelation rate increases the frequency at which aggregate productivity is exposed to the systemic shock which, for low $\bar{L}$, affects approximately half of the aggregate investment portfolio.

Figure 3 depicts, for a particular numerical example, how the probability density function of A and the revelation rate ρ^* change with $\bar{\alpha}$. In particular, I consider the case where idiosyncratic shocks are symmetric, while the systematic shock is, most of the time, slightly above it average and rarely much below it. This generates an asymmetric distribution of S characterized by negative skewness, which captures the notion that negative systematic events are rare but very destructive since, for instance, they trigger the disruption of part of the financial market and large scale liquidations. I also use the standard parametrization $\psi = \frac{1}{\gamma} = 0.5$ and the relative information cost ξ is set equal 1.005% . As expected,

[5] If $\bar{L} \simeq 0$ then $\eta^* \simeq 0$ and A reflects the portfolio choice of only passive investors. This restriction has no qualitative consequence for our discussion, since the business cycle properties are linked to ρ^*, which does not depend on $\bar{L}$.

[6] See Appendix C.

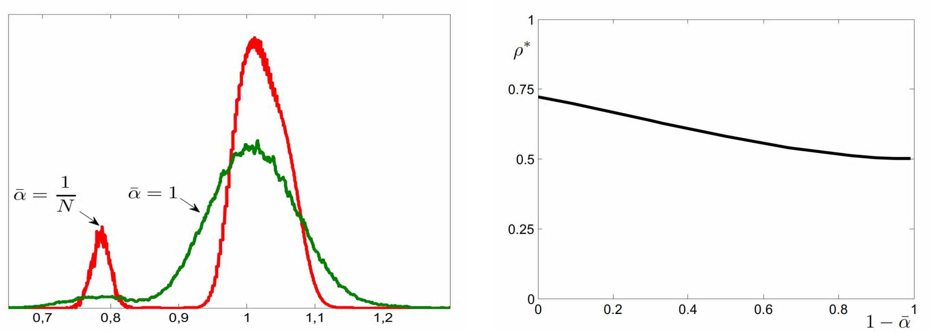

Figure 3: Probability density function of A (left panel) and revelation rate (right panel) for minimum ($\bar{\alpha} = 1/N$) and maximum ($\bar{\alpha} = 1$) barrier to diversification. With equal probability $i_m \in \{1.18, 0.82\}$ and $e_m \in \{1.18, 0.82\}$; $S = 1.1$ with probability 0.82 and $S = 0.57$ otherwise; $N = 120$; $\xi = 1.005$; $\beta = 0.97$; $\psi = 1/\gamma = 0.5$; $p_h = 0.18 \cdot 0.82^{h-1}$. Computed volatilities: $\sigma_A^2(\bar{\alpha} = 1) = 6.3 \cdot 10^{-3}$, $\sigma_A^2(\bar{\alpha} = 1/N) = 5.5 \cdot 10^{-3}$.

the equilibrium revelation rate decreases as the barrier $\bar{\alpha}$ decreases. Since σ_A^2 decreases, the reduction in $\hat{\sigma}_\omega^2$ turns out to be the dominating effect on aggregate volatility, while the sensitivity $\gamma_{A,S}$ to the asymmetric systematic shocks, representing negative "tail risk", increases.

The next section shows how systemic tail risk can be endogenously generated by financial innovation.

4 Information cycles and liquidation crises

In this section I study the consequences of financial innovation in a multi-period model when the risk structure of the economy changes over time, creating endogenous information cycles and sudden liquidations of excess risk technologies. The main setup is similar to the one presented in the previous section, with three main differences. First, the economy lasts three periods $t = 1, 2, 3$ and information and investment choices are made both at the beginning of time 1 and of time 2. Second, the structure of excess risk is time varying, since it is all idiosyncratic at time 1 and all systemic at time 2. Third, the systemic shock at time 2 is partly endogenous, since it depends on the possibility of a "liquidation crisis". Liquidation shocks take the form of a reduction δ in the time 2 returns of all technologies and occurs if, at the beginning of time 2, public information reveals the types to previously uninformed investors, thus triggering a wave of liquidations of their investments in excess risk technologies. The aggregate liquidation cost δ can be interpreted, for instance, as capital adjustment costs arising from the liquidation and reinvestment of capital from excess risk technologies to low risk technologies. Alternatively, δ could be the productivity

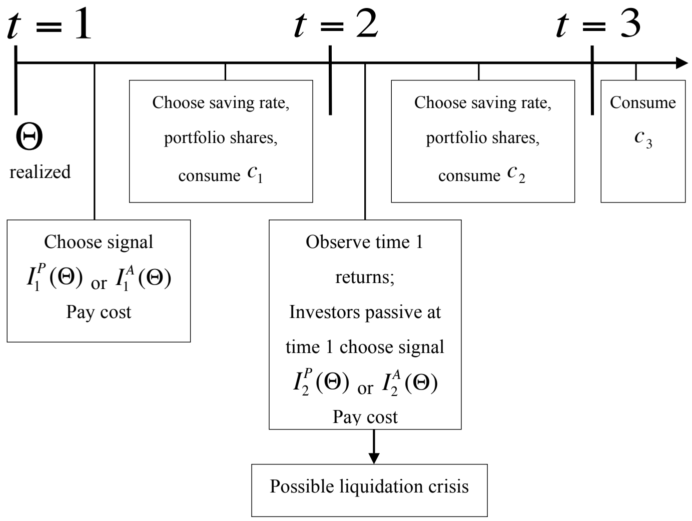

Figure 4: The extended model with time varying risk: sequence of actions.

costs of a banking crisis, triggered by financial intermediaries losses in the liquidation of excess risk technologies, similarly to Diamond and Rajan (2009) and Diamond (1991). The probability of a liquidation crisis is endogenous, since it depends on the public information revelation rates, which are ultimately related to the vector of distortions D. Under quite general assumptions I will show that, absent a reduction in the relative cost of information, financial innovation decreases welfare because it increases the probability of liquidation crises. The reason is that financial development creates incentives to collect less information during times when excess risk is idiosyncratic, but does not affect information collection during periods when excess risk is systemic. In the terms of the model, lower distortions D decrease the revelation rate at time 1, but does not change the revelation rate at time 2. Consequently, the probability that at time 1 the economy undertakes investments in excess risk technologies increases, and thus the probability of a liquidation crisis at time 2 raises.

Much of the basic structure of the problem is based on the simple two period model in Section 3. The timeline is sketched in Figure 4. At the beginning of time 1, agents draw a specialization h and a type Θ is realized; depending on their choice $\tau_1 = A, P$, agents pay the cost ξ_{τ_1}, observe the signal $I_1^{\tau_1}$ and make investment choices. At the beginning of time 2, time 1 returns are realized and observed; if, at this point, agents that chose $\tau_1 = P$ are still uninformed, they have another chance to choose $\tau_2 = A$, pay the cost, and join the group of active investors, or choose $\tau_2 = P$ and remain passive; time 2 signals $I_2^{\tau_2}$ are observed and new investment decisions are made. At the beginning of time 3 returns from

time 2 investments are realized and agents consume all the proceeds.
I consider the analytically simplest extension of (9) to the three period case by assuming that the utility function has the following logarithmic[7] form

$$V_{1,I} = \exp\{(1-\beta)\ln c_{1,I} + \beta U_2\} \tag{22}$$
$$V_{2,I} = \exp\{(1-\beta)\ln c_2 + \beta E \ln c_{3,I}\} \tag{23}$$

where, for $t = 1, 2$

$$U_t = E \ln V_{t,I}$$

For $t = 1, 2$ call $r_{m,j,t}$ the return technology (m, j) between time t and $t+1$. Assume that

$$r_{m,3-\theta_m,1} = 1 \tag{24}$$
$$r_{m,3-\theta_m,2} = 1 - I_2^\lambda \delta \tag{25}$$
$$r_{m,\theta_m,1} = 1 + S_1(e_m - 1) \tag{26}$$
$$r_{m,\theta_m,2} = (1 - I_2^\lambda) S_2 \tag{27}$$

The support of S_1 is the set binary $\{0, 1\}$ and $\text{Prob}\{S_1 = 1\} = \pi_s$. Shocks S_2 and e_m are i.i.d., have mean equal to 1, satisfy $e_m, S_2 \neq 1$ almost surely and are independent on S_1 and on I_t^P. Notice that $S_1 = 1$ corresponds to a state of excess idiosyncratic risk at time 1, while if $S_1 = 0$ excess risk is absent. Moreover, at time $t = 2$ the economy is overall more risky, since all the excess risk becomes systemic. This is due to the assumption that S_2 and e_m are identically distributed: the economy is riskier not because risk increases for any given technology, but because excess risk becomes perfectly correlated across markets, and it thus not diversifiable. I now turn to the characterization of a liquidation crisis, with its associated costs $\delta \in (0, 1)$. The indicator function I_2^λ equals 1 if a liquidation crisis occurs at time 2, and zero otherwise. From our previous discussion it follows that

$$I_2^\lambda = (1 - I_1^\rho)[S_1 + (1 - S_1) I_2^\rho] \tag{28}$$

Equation (28) implies that a necessary condition for the occurrence of a liquidation crisis at time 2 is that public information at time 1 is not revealing ($I_1^\rho = 0$), so that passive agents undertake investments at time $t = 1$ in the excess risk technologies. Liquidation of these investments takes place if types are revealed at time 2. This happens either because excess idiosyncratic volatility ($S_1 = 1$) allows passive investors to learn types from the observation of end-of-period 1 returns[8], or if the time 2 public signal is revealing ($I_2^\rho = 1$). Therefore,

$$\pi_\lambda = \text{Prob}\{I_2^\lambda = 1\} = (1 - \rho_1)[\pi + (1 - \pi)\rho_2] \tag{29}$$

[7]The qualitative results presented do not depend on the logarithmic form. The full extension of utility (9) to a multiperiod case can be done using Epstein and Zin (1989) recursive preference. This more general setting is available upon request from the author.

[8]There is no learning when $S_1 = 0$, since technologies have identical return at time 1.

where ρ_t are the revelation rates at time t associated with two mutually independent[9] shocks I_t^ρ as in (6).
The complete solution to the model is provided in Appendix D. The crucial variables to be derived are the revelation rates ρ_t. Consistently with the results of Section 3, ρ_t will depend on the relative value at t of the risk adjusted returns. Call $\hat{r}_{1,I}^h$ the (unadjusted) return at $t = 1$ to the portfolio of an informed ($I = \Theta$) and uninformed ($I = \mathbf{0}$) agent. We have

$$\hat{r}_{1,0}^h = \frac{1-\bar{\alpha}}{N-1} \sum_{m \neq h} \frac{1 + r_{m,\theta_m,1}}{2} + \bar{\alpha} \frac{1 + r_{h,\theta_h,2}}{2} \tag{30}$$

$$\hat{r}_{1,1}^h = 1 \tag{31}$$

The return $\hat{r}_{2,I}^h$ at time 2 to the portfolio of an investor with information $I = \Theta, \mathbf{0}$ is

$$\hat{r}_{2,0}^h = (1 - I_2^\rho \delta) \frac{1 + S_2}{2}$$
$$\hat{r}_{2,\Theta}^h = 1 - I_2^\rho \delta$$

Corresponding to the unadjusted returns $\hat{r}_{t,I}^h$, the risk-adjusted returns are given by $R_{t,I}$, where

$$R_{t,I} = \exp E \ln r_{t,I}^h$$

for all h.

Proposition 3. *Consider an equilibrium with interior revelation rate $\rho_1^* > 0$. Then,*

$$\rho_t^* = 1 - \frac{\ln \xi}{\beta \ln \frac{R_{t,\Theta}}{R_{t,0}}} \tag{32}$$

with $\rho_2^* > \rho_1^*$. Moreover ρ_1^* decreases, ρ_2^* is unchanged and welfare decreases if the barrier $\bar{\alpha}$ decreases.

Proof. Equation (32) is derived in Appendix D. We want to demonstrate that $\rho_2^* > \rho_1^*$, or

$$\ln \frac{R_{2,0}}{R_{2,\Theta}} = E \ln \frac{\hat{r}_{2,0}^h}{\hat{r}_{2,\Theta}^h} < \ln \frac{R_{1,0}}{R_{1,\Theta}} = E \ln \frac{\hat{r}_{1,0}^h}{\hat{r}_{1,\Theta}^h}$$

It suffices to show that these inequalities hold when $\bar{\alpha} = 1$, since $R_{2,I}$ is unaffected by $\bar{\alpha}$ while $R_{1,0}$ is decreasing in $\bar{\alpha}$ and $R_{\Theta,1} = 1$. Since e_m and S_2 are identically distributed we have, for $\bar{\alpha} = 1$,

$$\frac{\hat{r}_{2,0}^h}{\hat{r}_{2,\Theta}^h} = \frac{\hat{r}_{1,0}^h}{\hat{r}_{1,\Theta}^h} + \varepsilon^h$$

[9] This is the case if liquidity noises L_t for $t = 1, 2$ are independent of each other.

where the equality is intended as equality in distribution and $\varepsilon^h = (e_h - 1)(1 - S_1)$. Notice that, since e_h and S_1 are independent,

$$E[\varepsilon^h | \hat{r}^h_{1,0} = 1] = E[\varepsilon^h | S_1 = 0] = 0$$

$$E[\varepsilon^h | \hat{r}^h_{1,0} \neq 1] = E[\varepsilon^h | S_1 = 1] = 0$$

therefore $\hat{r}^h_{2,0}/\hat{r}^h_{2,\Theta}$ is a mean preserving spread of $\hat{r}^h_{1,0}/\hat{r}^h_{1,\Theta}$ and this proves that $\rho^*_1 < \rho^*_2$. Finally, if $\mu^*_1 = \rho^*_1/A^E$ is the measure of active investors at time 1 then, conditional on $I^\rho_1 + S_1 = 0$, an extra measure $(\rho^*_2 - \rho^*_1)/A^E$ of previously passive investors become active at time 2. $\square$

If $\bar{\alpha}$ decreases ρ^*_2 is unchanged because there is only systemic risk at time 2, while ρ^*_1 decreases because there is idiosyncratic risk at time 1. Consequently, the probability π_λ of a liquidation crisis increases if $\bar{\alpha}$ is reduced. The effect on welfare is intuitive. The return at time 1 to the portfolio of an active investor is always $\hat{r}^h_{1,1} = 1$, while the return at time 2 equals $r^h_{2,1} = 1$ if there is no liquidation crisis and $r^h_{2,1} = 1 - \delta$ otherwise. As the probability of a liquidation crisis increases it becomes more likely that an active investor faces low returns $1 - \delta$ at time 2, which reduces her time 1 expected utility.

5 Conclusions

The empirical evidence suggests that financial innovation increases diversification opportunities and reduces investment costs, but does not reduce the relative cost of information. I construct an analytically tractable theoretical model that examines how financial innovation affects incentives to collect costly information about the riskiness of production technologies. I find that financial innovation tends to be associated with lower collection of private information and thus, via a spillover effect, with lower quality of public information. This result has important implications for the business cycle, since aggregate productivity becomes more subject to systemic shocks, even when its overall volatility decreases. Recent empirical evidence shows that in the US agents have indeed shifted over time from active to passive investment strategies. Higher diversification and lower investment costs improve welfare, even though the lower quality of information has a negative effects on passive investors. In an extended model where risk is time varying risk, financial innovation increases the probability of liquidity crises. In fact, financial innovation lowers information collection during periods in which excess risk is mainly idiosyncratic and thus increases the frequency at which uninformed agents mistakenly invest in excess risk technologies. Liquidity crises arise when the excess risk becomes systemic: information collection rises and triggers a wave of liquidation. If liquidation crises impose aggregate costs to the economy then financial innovation can decrease welfare. The paper shows that financial innovation and endogenous information collection can be intertwined in important ways. More research on this issue is certainly needed.

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Appendix A

I find the optimal portfolio shares $\alpha^*_{m,j}(I)$ and show that risk adjusted retruns decrease in the barrier $\bar{\alpha}$. The proof is in five steps.

Step 1) Assume $I = \mathbf{0}$. From the point of view of a passive investors, all technologies have identically distributed returns. The return on technology (j, m) can then be written as

$$r_{m,j} = (1 - |j - \theta_m|) i_m e_m S + |j - \theta_m| i_m$$

Notice that

$$r_{m,1} + r_{m,2} = i_m(1 + e_m S)$$

I show that any choice of portfolio shares $\nu^h_{j,m}$ such that $\nu^h_{h,1} + \nu^h_{h,2} = \bar{\alpha}$ provides less utility than the choice $\tilde{\alpha}^h_{m,j}$ such that

$$\begin{array}{ll} \tilde{\alpha}^h_{m,j} = \frac{1-\bar{\alpha}}{2} & m \neq h \\ \tilde{\alpha}^h_{j,m} = \nu^h_{m,j} & m = h \end{array}$$

Define

$$\begin{aligned} q_{\tilde{\alpha}} &= \sum_{(m,j)} \tilde{\alpha}^h_{m,j} r_{m,j} \\ &= (1 - \bar{\alpha}) \sum_m i_m(1 + e_m S) + \sum_j \nu^h_{m,j} r_{m,j} \\ q_\nu &= \sum_{(m,j)} \nu^h_{m,j} r_{m,j} \\ \tilde{z} &= \sum_{(m,j), m \neq h} (\nu^h_{m,j} - \tilde{\alpha}^h_{m,j}) r_{m,j} \end{aligned}$$

Notice that

$$q_\nu = q_{\tilde{\alpha}} + \tilde{z}$$

Since i_m and e_m are i.i.d. across m we have

$$E[i_m | q_{\tilde{\alpha}}] = E[i_n | q_{\tilde{\alpha}}] \quad m, n \neq h$$

$$E[e_m | q_{\tilde{\alpha}}] = E[e_n | q_{\tilde{\alpha}}] \quad m, n \neq h$$

Therefore,

$$E[r_{m,j} | q_{\tilde{\alpha}}] = E[r_{n,k} | q_{\tilde{\alpha}}] \equiv r \quad j, k = 1, 2 \quad m, n \neq h$$

and then

$$E[\tilde{z} | q_{\tilde{\alpha}}] = r \sum_{(m,j), m \neq h} (\nu^h_{m,j} - \tilde{\alpha}^h_{m,j}) = 0$$

q_ν is a mean preserving spread of $q_{\tilde{\alpha}}$, then by Jensen's inequality

$$E[(q_{\tilde{\alpha}})^{1-\gamma}]^{\frac{1}{1-\gamma}} \geq E[(q_\nu)^{1-\gamma}]^{\frac{1}{1-\gamma}}$$

Step 2) Assume $I = \mathbf{0}$. I show that the portfolio $\tilde{\alpha}$ constructed in Step 1 is dominated by portfolio α with

$$\begin{array}{ll} \alpha^h_{m,m} = \tilde{\alpha}^h_{m,m} & m \neq h \\ \alpha^h_{m,j} = \frac{\bar{\alpha}}{2} & m = h \end{array}$$

Similarly to Step 1 define q_α and z as

$$q_\alpha = (1-\bar{\alpha})\sum_m i_m(1+e_mS) + \frac{\bar{\alpha}}{2} i_h(1+e^hS)$$
$$z = \sum_j (\tilde{\alpha}^h_{h,j} - \alpha^h_{h,j}) r_{h,j}$$

Since q_α is independent of Θ it follows that

$$E[r_{h,1}|q_\alpha] = E[r_{h,2}|q_\alpha]$$

and then again $E[z|q_\alpha] = 0$. Since $q_{\tilde{\alpha}} = q_\alpha + z$ then $q_{\tilde{\alpha}}$ is a mean preserving spread of q_α.

Step 3) Assume $I = \Theta$. I show that any choice of portfolio shares $\nu^h_{m,j}$ such that $\nu^h_{h,1} + \nu^h_{h,2} = \bar{\alpha}$ provides less utility than the choice $\alpha^h_{m,j}$ such that

$$\begin{array}{ll} \alpha^h_{m,3-\theta_m} = \nu^h_{m,1} + \nu^h_{m,2} & \forall m \\ \alpha^h_{m,\theta_m} = 0 & \forall m \end{array}$$

Define q_ν, q_α as usual as the returns of portfolios ν and α, and define z as

$$z = \sum_m \nu_{m,3-\theta_m}(e_mS - 1)i_m$$

Since e_m and S are independent from q_α, then $E[z|q_\alpha = 0]$. The portfolio $q_\nu = q_\alpha + z$ is a mean preserving spread of q_α.

Step 4) Assume $I \in \{\Theta, \mathbf{0}\}$. For any $\bar{\alpha}$ I have constructed in Step 2-3 two corresponding portfolios $\alpha^h_{m,j}(\bar{\alpha})$ as a function of the barrier $\bar{\alpha}$. For an agent with specialization h and information I, the corresponding return q_α satisfies $q_\alpha(\bar{\alpha}) = \hat{r}^h_I(\bar{\alpha})$, with r^h_I given in Section 3. We can write

$$\hat{r}^h_I(\bar{\alpha}) = (1-\bar{\alpha})\sum_{m\neq h} r_m + \bar{\alpha} r_h$$

where r_m is the average return in market m obtained by averaging the contribution of each technologies $j = 1, 2$ using weights $\frac{\alpha^h_{m,j}}{\alpha^h_{m,1}+\alpha^h_{m,2}}$. We can write,

$$\hat{r}^h_I(\bar{\alpha}) = \hat{r}^h_I(1/N) + \phi z$$

$$\phi = \frac{N\bar{\alpha} - 1}{N}$$

$$z = r_h - \frac{1}{N-1}\sum_{m \neq h} r_m$$

It is easy to show that $E[z|\hat{r}^h_I \alpha(1/N)] = 0$. Without loss of generality assume that $\gamma < 1$. Choose $\bar{\alpha}' > \bar{\alpha} \geq \frac{1}{N}$ so that $\phi' > \phi \geq 0$. Notice that, by concavity,

$$\begin{aligned}
[\hat{r}^h_I(1/N) + \phi z]^{1-\gamma} &= \left\{ \frac{\phi}{\phi'}[\hat{r}^h_I(1/N) + \phi' z] + \left(1 - \frac{\phi}{\phi'}\right)\hat{r}^h_I(1/N) \right\}^{1-\gamma} \\
&> \frac{\phi}{\phi'}\left[\hat{r}^h_I(1/N) + \phi' z\right]^{1-\gamma} + \left(1 - \frac{\phi}{\phi'}\right)[\hat{r}^h_I(1/N)]^{1-\gamma}
\end{aligned}$$

Conditional on any value of $\alpha(1/N)$, Jensen's inequality gives

$$\begin{aligned}
E[\hat{r}^h_I(1/N) + \phi z]^{1-\gamma} &> \frac{\phi}{\phi'}E\left[\hat{r}^h_I(1/N) + \phi' z\right]^{1-\gamma} + \left(1 - \frac{\phi}{\phi'}\right)[\hat{r}^h_I(1/N)]^{1-\gamma} \\
&> \frac{\phi}{\phi'}E\left[\hat{r}^h_I(1/N) + \phi' z\right]^{1-\gamma} + \left(1 - \frac{\phi}{\phi'}\right)E[\hat{r}^h_I(1/N) + \phi' z]^{1-\gamma} \\
&= E[\hat{r}^h_I(1/N) + \phi' z]^{1-\gamma}
\end{aligned}$$

This proves that as $\bar{\alpha}$ decreases the risk adjusted return of the investors' portfolios increase.

Appendix B

In this appendix I present the signal extraction problem of passive investors. Choose any market m. For $j = 1, 2$ define

$$L_j = \frac{y(m, j)}{\omega_m}$$

The realization of the noise L satisfies $L \in \{L_1, L_2\}$. Hence, for every every market m' and $j' = 1, 2$ it must be the case that $\frac{y(m',j')}{\omega_m} \in \{L_1^\theta, L_2^\theta\}$. In particular, suppose that $L = L_j$, then

$$\frac{y(m', j')}{\omega_m} = L_j \Leftrightarrow \theta_m = j'$$

In this way, we associate to each realization $L = L_j$ one and only one vector of types. More precisely, for a realization $\hat{\mathbf{y}}$, call Θ_j the unique vector of types associated with the event $\{L = L_j\} \cap \{\mathbf{y} = \hat{\mathbf{y}}\}$. Notice that the true type Θ satisfies

$$\Theta_{\theta_m} = \Theta$$

where θ_m is type true realization in our reference market m. Notice also that

$$\Theta_j = \bar{\Theta}_{3-j} \tag{33}$$

Using Bayes rule (for continuous variables) and the arguments above we have

$$\begin{aligned}
\text{Prob}\{\Theta = \Theta_j | \mathbf{y} = \hat{\mathbf{y}}\} &= \text{Prob}\{L = L_j | \mathbf{y} = \hat{\mathbf{y}}\} \\
&= \frac{u(L_j)\text{Prob}\{\mathbf{y} = \hat{\mathbf{y}} | L_j\}}{u(L_j)\text{Prob}\{\mathbf{y} = \hat{\mathbf{y}} | L_j\} + u(L_{3-j})\text{Prob}\{\mathbf{y} = \hat{\mathbf{y}} | L_{3-j}\}} \\
&= \frac{u(L_j)F(\Theta_j)}{u(L_j)F(\Theta_j) + u(L_{3-j})F(\Theta_{3-j})}
\end{aligned}$$

where u is the probability density function of L. Using (3) and (33) we conclude that

$$\text{Prob}\{\Theta_j | \mathbf{y}\} = \frac{u(L_j)}{u(L_j) + u(L_{3-j})}$$

Appendix C

This appendix computes the business cycle statistics and establishes the monotonicity of $\hat{\sigma}^2_\omega$ in $\bar{\alpha}$.
Define

$$\begin{aligned} A_\Theta =& \sum_m \omega_m i_m \\ A_0 =& \frac{1}{2}\sum_m \omega_m i_m (1 + e_m S) \end{aligned}$$

Conditional on an informative signal $I^P = \Theta$ all the agents invest in the low risk technologies, thus the productivity A is

$$A = A_\Theta$$

If $I^P = \mathbf{0}$ passive investors split equally their portfolio between the low risk and excess risk technologies and then

$$\begin{aligned} A =& \frac{(1-\eta^*)\xi x_0^* A_0 + \eta^* x_\Theta^* A_\Theta}{(1-\eta^*)\xi x_0^* + \eta x_\Theta^*} \\ =& A_0 + \frac{\eta^* x_\Theta^* (A_\Theta - A_0)}{(1-\eta^*)\xi x_0^* + \eta^* x_\Theta^*} \end{aligned}$$

Recalling that $\eta^* = \rho^*/A^E$ we derive the unconditional covariance $Cov(A, S)$ as

$$\begin{aligned} Cov(A,S) =& E[Cov(A,S|I=\mathbf{0})] + E[Cov(A,S|I=\Theta)] \\ =& E[Cov(A,S|I=\mathbf{0})] \\ =& E[Cov(A_0,S|I=\mathbf{0})] + \frac{E\left[Cov(A_\Theta - A_0, S|I=\mathbf{0})\right] x_\Theta^* \rho^*/A^E}{(1-\rho^*/A^E)\xi x_0^* + x_\Theta^* \rho^*/A^E} \\ =& E\left[Cov(A_0,S|I=\mathbf{0})\right] + O(\bar{L}) \\ =& (1-\rho^*)Cov(A_0,S) \\ =& \frac{1}{2}(1-\rho^*)\sigma_S^2 \end{aligned}$$

The unconditional variance is

$$\begin{aligned}
\sigma_A^2 =& E[Var(A|I=\mathbf{0})] + E[Var(A_\Theta|I=\Theta)] \\
=& E[Var(A_0|I=\mathbf{0})] + \left(\frac{x_\Theta^* \rho^*/A^E}{(1-\rho^*/A^E)\xi x_0^* + x_\Theta^* \rho^*/A^E}\right)^2 E\left[Var(A_\Theta - A_0, S|I=\mathbf{0})\right] \\
&+ \frac{2x_\Theta^* \rho^*/A^E}{(1-\rho^*/A^E)\xi x_0^* + x_\Theta^* \rho^*/A^E} E[Cov(A_0; A_\Theta - A_0|I=\mathbf{0}] + E[Var(A_\Theta|I=\Theta)] \\
=& E[Var(A|I=\mathbf{0})] + E[Var(A_0|I=\Theta)] + O(\bar{L}) \\
=& (1-\rho^*)Var(A_0) + \rho^* Var(A_\Theta) + O(\bar{L})
\end{aligned}$$

For the dispersion $\hat{\sigma}^2$ notice that

$$\omega_m \leq \frac{1}{N} \Leftrightarrow p_m \leq \frac{1}{N}$$

$$\frac{\partial \omega_m}{\partial(1-\bar{\alpha})} \geq 0 \Leftrightarrow p_m \leq \frac{1}{N}$$

Therefore,

$$\frac{\partial \omega_m}{\partial(1-\bar{\alpha})} \geq 0 \Leftrightarrow \omega_m \leq \frac{1}{N}$$

The above equation established that the variance σ_ω^2 of ω_m is decreasing in $1-\bar{\alpha}$,

$$\sigma_\omega^2 = \frac{1}{N}\sum_m \left(\omega^m - \frac{1}{N}\right)^2 = \frac{\tilde{\sigma}_\omega^2}{N} - \frac{1}{N^2}$$

Since $\hat{\sigma}_\omega^2 = N\sigma_\omega^2 + \frac{1}{N}$, then also $\hat{\sigma}_\omega^2$ decreases in $1-\bar{\alpha}$.

Appendix D

Here I provide the solution to the extended model. The revelation rates ρ_t are solved by backward induction. Conditional on $I_1^\rho + S_1 = 0$, call $V_{2,I}(w)$ the value at time 2 of a passive investor with information $I \in \{\Theta, \mathbf{0}\}$ and wealth w,

$$V_{2,I}(w) = \max_x \exp\{(1-\beta)\ln(1-x)w + \beta E \ln xw\hat{r}^h_{2,I}\}$$

The first order condition gives $x^* = \beta$ which implies

$$V_{2,I}(w) = w(1-\beta)^{1-\beta}\beta^\beta(R_{2,I})^\beta$$

The revelation rate ρ_2^* is found by equalizing at any state the expected continuation value U_2, per unit of wealth, of an active investor to that of an passive,

$$E \ln V_{2,\Theta}(1/\xi_A) = \rho_2^* E \ln V_{2,\Theta}(1/\xi_P) + (1-\rho_2^*)V_{2,0}(1/\xi_P)$$

Recall that, conditional on $I_1^\rho + S_1 = 0$, the revelation of information ($I_2^\rho = 1$) at time 2 causes all technologies to suffer a liquidation cost δ. Solving the equation above gives the revelation rate ρ_2^*.
Given a continuation value U_2 per unit of wealth, the revelation rate ρ_1^* is found by equating the value U_1, per unit of wealth, of an active and passive investor at the beginning of time 1. Define the values $V_{1,I}(w)$ as

$$V_{1,I}(w) = \max_x \exp\{(1-\beta)\ln(1-x)w + \beta E \ln xw\hat{r}^h_{1,I}U_2\}$$

The optimal investment is again $x = \beta$. The solution is

$$V_{2,I}(w) = w(1-\beta)^{1-\beta}\beta^\beta(R_{1,I})^\beta E U_2^\beta$$

The revelation rate ρ_1^* then solves the following equation

$$\ln V_{1,\Theta}(w/\xi_A) = \rho_1^* \ln V_{1,\Theta}(w/\xi_P) + (1-\rho_1)\ln V_{1,0}(w/\xi_P)$$

Appendix E

This appendix provides details for the construction of the series in Figure 1. All data are taken from the Tables in French (2008). Starting from the top panel, the active and passive costs for DB plans are reported in Table III. For the bottom panel, the cost of the composite passive strategy is given in Table VII, column "Total Cost". I construct the composite active strategy as a weighted average of investments in mutual funds, pension funds and hedge funds. The weight for the mutual funds is constructed using the market share for Open-end funds in Table I. This probably slightly overestimates by how much this component has decreased, since mutual funds has shifted overtime towards passive strategies, which are less costly. Nonetheless in 2006 as much as 88% of the Open-end funds are defined as active (Table II). The weight of the pension funds is constructed summing the shares of DB plans and DC plans in Table I. The weight for hedge funds is constructed using the share in Table I. The cost of Open-end funds is given in Table II, column "Total". The costs of pension funds is the cost of active DB plans in Table III. The cost of the hedge funds is the one reported in Table IV under "Hedge Fund plus Fund of Funds"; I fill the missing values for dates prior to 1996 by using 9.27%, which is the 1996 value. This has no significant impact on the estimation of the cost index, since hedge funds have weights smaller than 2.3% for the years prior to 1996.

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