TSE working paper series

10-200

Research Group: *Finance in Toulouse*

October, 2010

Innovations, Rents and Risk

BRUNO BIAIS, JEAN-CHARLES ROCHET

AND PAUL WOOLLEY

Innovations, rents and risk

Bruno Biais[1], Jean–Charles Rochet[2] and Paul Woolley[3]

September 2010

This research was conducted within the Paul Woolley Research Initiative on Capital Market Dysfunctionalities at IDEI, Toulouse. Support from the Europlace Institute of Finance is gratefully aknowledged. Many thanks to participants in the first conference of the Centre for the Study of Capital Market Dysfunctionality at the London School of Economics, the Pompeu Fabra Conference on the Financial Crisis, the third Banco de Portugal conference on Financial Intermediation, the Europlace Institute of Finance 7th Annual Forum, as well as seminar participants at London Business School, Frankfurt University, the European Central Bank and Amsterdam University, especially Sudipto Bhattacharya, Arnoud Boot, John Boyd, Markus Brunnermeier, Catherine Casamatta, Zvi Eckstein, Guido Friebel, Alex Gümbel, Philipp Hartmann, Augustin Landier, Thomas Mariotti, John Moore, Liliana Pellizzon, Enrico Perotti, Ludovic Phalippou, Guillaume Plantin and Steve Schaefer.

[1]Toulouse School of Economics (CNRS-GREMAQ & PWRI-IDEI)

[2]Toulouse School of Economics (CNRS-GREMAQ & PWRI-IDEI)

[3]London School of Economics (PWC)

Abstract

We offer a rational expectations model of the dynamics of innovative industries. The fundamental value of innovations is uncertain and one must learn whether they are solid or fragile. Also, when the industry is new, it is difficult to monitor managers and make sure they exert the effort necessary to reduce default risk. This gives rise to moral hazard. In this context, initial successes spur optimism and growth. But increasingly confident managers end up requesting large rents. If these become too high, investors give up on incentives, and default risk rises. Thus, moral hazard gives rise to endogenous crises and fat tails in the distribution of aggregate default risk. We calibrate our model to fit the stylized facts of the MBS industry's boom and bust cycle.

1 Introduction

Innovation waves often spur boom and bust cycles. Uncertainty, learning and information asymmetry are key features of such waves. We offer a dynamic rational expectations model where they generate initial growth, followed by rents, fat tails in the distribution of aggregate defaults and endogenous crises.

In our model, the value of the innovation is uncertain and agents progressively learn about it.[4] With some probability the innovation is robust, otherwise it is fragile. In the former case, default risk in the innovative sector is low, while in the latter case it is somewhat larger. As time goes by and the performance of the innovative sector is observed, investors and managers conduct rational Bayesian learning. When low aggregate default rates are observed, beliefs about the strength of the innovative sector improve. This leads to an increase in its size, as well as in the compensation of its managers. In contrast, if defaults are frequent, this generates pessimism and leads to a decline in the size of the innovative sector.[5]

In practice, innovative sectors are likely to be plagued by information asymmetries. It is hard for outsiders to understand everything insiders do, and to precisely monitor their actions. We assume that, in the innovative sector, each manager must exert costly and unobservable effort to reduce the probability of failure of his project.[6] For example, one can think of the project as investing in a portfolio of CDOs. If the manager exerts effort, he carefully scrutinizes the quality of the paper he invests in. Alternatively, the manager can opt for risk–taking and fail to exert the effort requested by such an analysis. In that case he would rely on ready made evaluations, such as those obtained from credit rating agencies. Furthermore, managers are assumed to have limited liability. This curbs the ability to punish failure. Hence, to provide incentives for risk–prevention effort, investors must promise rewards to agents in case of success. When the moral hazard problem is severe, such rewards

[4] In our analysis, uncertainty means that the parameters are not known for sure. Agents conduct bayesian learning about these parameters. This differs from Caballero and Krishnamurthy (2008), who shed light on financial crises within a Knightian uncertainty framework.

[5] Thus our analysis is in line with Zeira (1987, 1999), Rob (1991), Pastor and Veronesi (2006), and Barbarino and Jovanovic (2007), who show that learning induces fluctuations in industry size.

[6] In our model, the project can be successful or fail. In the latter case it generates 0 cash and investors can't be repaid. This can be interpreted as default and, in our paper, the terms "failure" and "default" will both refer to that outcome.

are above the market clearing wage, i.e., managers in the innovative sector earn rents, although they are competitive.

While shirking increases the probability of default, we assume that this increase in risk is stronger when the innovation is fragile than when it is solid. This is plausible, as strong industries are likely to be more robust to shirking than fragile ones. Under this assumption, after several years of success, managers become very confident that the industry is solid. This makes it hard to induce them to exert effort, as they think it likely that the project will be successful even if they shirk. Thus, after a confidence buildup, agency rents grow very large. At some point, investors may find it cheaper to give up on incentives, to avoid paying excessively large fees. In that case equilibrium actions switch from effort to risk–taking.[7] This switch in the equilibrium action of each individual manager distorts the distribution of outcomes towards more frequent failures, thus it generates fat tails in the distribution of aggregate defaults. Since the burst in aggregate default results from equilibrium actions, we interpret it as an endogenous financial crisis. Note that, in the symmetric information version of our model, managers always exert the risk–prevention effort and therefore there are no crises.[8]

Our key assumptions are particularly relevant for financial innovation waves. Because finance is intangible and complex, learning and information asymmetry are likely to be particularly important features of this industry. Indeed, the equilibrium dynamics arising in our model are in line with empirical evidence on the recent financial innovation wave and ensuing crisis. In our model, initial successes are followed by an increase in the complexity of jobs and the magnitude of rents in the finance sector. This is consistent with the empirical results of Philippon and Resheff (2009). We offer a calibration of our model, based on the assumption that there was no negative aggregate shock during the heydays of the "great moderation period", from 2002 to 2005. In this calibration, there is a switch to the risk–taking regime in 2005. This offers a rationale for the empirical finding by Demyanyk and Van Hemert (2008) that, for loans originated around that point in time, there is an increase in default

[7] In our model, agents must choose between risk–prevention effort and shirking. In a richer model there could be several levels of effort. In that case, the level of effort requested would decline in response to the rise in rents. Correspondingly, there would be a sequence of equilibrium regimes, with increasingly high default risk.

[8] Thus our main message differs from that of Zeira (1987, 1999), Rob (1991), Pastor and Veronesi (2006), and Barbarino and Jovanovic (2007). In their analyses, information is symmetric and crises can arise exogenously, while in our analysis crises arise endogenously because of information asymmetry.

risk that cannot be explained by exogenous variables. Furthermore, in the calibration, the regime switch occuring in 2005 triggers a shift in the distribution of aggregate defaults towards more risk. Thus, while in the effort regime aggregate default rates are between 0 and 6% in line with what has been observed between 2002 and 2005, in the risk–taking regime, aggregate default rates vary between 12% and 28%, in line with what has been observed after 2005 (see e.g., Jaffee 2008). These figures illustrate that in our model fat tails and endogenous crises can arise in equilibrium.

While shedding light on the potential costs of financial innovation waves, our analysis offers guidance to regulators in monitoring this process. First, the switch to an equilibrium regime with risk–taking occurs when rents in the financial sector are large. Therefore such rents offer an early signal that systemic risk is rising. Second, without moral hazard there is no risk–taking, i.e., information asymmmetry is at the root of the crisis. Such asymmetry can be partially mitigated by increased transparency, in markets (e.g., exchanges versus OTC) or in the disclosure of positions and trades (e.g., to regulators or CCPs). Third, combining the two above implications, its is particularly important to insist on transparency after waves of successful innovations, breeding high confidence and large rents.

The next section presents our model. Section 3 analyzes the benchmark case where effort is observable. Section 4 turns to the asymmetric information case. Section 5 presents the empirical implications and calibration of the model. Section 6 concludes. Proofs are in the appendix.

2 The model

2.1 Agents and goods

Consider an infinite horizon economy, operating in discrete time at periods $t = 1, 2, ...$ At each period, there is a mass one continuum of competitive managers and a mass one continuum of competitive investors. All agents are risk neutral. The managers have limited liability and no initial wealth. At the beginning of each period, each investor is endowed with one unit of nonstorable investment good. At the end of each period, all agents consume the consumption good, produced, as explained below, by labor and capital. For simplicity, we focus on the simplest possible case, where managers live and contract only for one period.[9] Yet, the model is dynamic, to the extent that agents progressively learn about the strength of the innovative industry. Thus, the link between generations runs through the evolution of beliefs.

2.2 The two sectors

2.2.1 Managers and investors

There are two sectors, the traditional sector and the innovative one. Managers and investors are heterogeneous. Their types are denoted by ν and ρ respectively. The types of the managers are distributed over $[0, \bar{\nu}]$. Their cumulative distribution function is denoted by G. The types of the investors are distributed over $[0, \bar{\rho}]$. Their cumulative distribution function is denoted by F. Managers and investors choose in which sector to operate. For simplicity we assume that, in the traditional sector, agents generate output equal to their type. Thus, when a type ν manager operates in the traditional sector, he obtains, at the end of the period, ν units of the consumption good. Similarly, when investor ρ allocates her unit endowment of investment good to the traditional sector, she obtains ρ units of the consumption good at the end of the period.

Operating the innovative technology requires one unit of investment as well as one manager. Capital is provided by the investors, who are endowed with the investment good at the beginning of the period. Managers, who can't work on more than one project, are hired by investors. For example the agent could be an investment banker, using the capital to undertake innovative financial engineering operations, e.g., in structured finance.

2.2.2 Shocks and uncertainty

The innovative industry can be hit by negative shocks, increasing default rates. Because it's an innovation, in the beginning it is difficult to evaluate its profitability. To model this we assume that, a priori, there is uncertainty about the exposure of the innovative industry to negative shocks. With some probability the innovation is strong (an event denoted by $\theta = 1$). In this case the likelihood of

[9] When players interact for several periods, shirking can create a wedge between the beliefs of investors and managers. Bergemann and Hege (1998, 2005) and DeMarzo and Sannikov (2008) offer insightful analyses of this problem.

negative shocks is small and equal to $1 - \bar{p}$. Alternatively, the innovation is fragile ($\theta = 0$), in which case the probability of negative shocks is equal to $1 - \underline{p} > 1 - \bar{p}$.

Consider for example resecuritization techniques, such as CDOs of ABSs. They were designed to reallocate risk, thus enhancing risk sharing and liquidity. But the reliability and effectiveness of this innovation was not fully clear ex–ante. A strong innovation would have relatively little exposure to shocks, so that investors holding highly ranked tranches would run relatively little risk. In contrast, a fragile innovation would have greater exposure to negative shocks, characterized by large default rates.

2.2.3 Moral hazard

Each firm's output depends on the effort of its manager. Managerial effort leads to an improvement in the distribution of output in the sense of first order stochastic dominance. This can be interpreted in terms of risk prevention, e.g., fund managers and bankers can exert effort to screen investment opportunities, and avoid those with a large risk of default.

First consider the case where managers exert effort. In that case, if there is no negative shock, innovative firms obtain output Y. On the other hand, if there is a negative shock, for each innovative firm there is a probability μ that the output is 0, while with the complementary probability output is Y. Conditional on the negative shock, firms' outputs are i.i.d., hence, by the law of large numbers, there is a fraction μ of firms that fail, while the remaining $1 - \mu$ firms succeed.

Now turn to the case where the manager doesn't exert effort. This increases the risk that output will be 0. When the innovative industry is strong, the increase in the probability of default generated by shirking is $\underline{\Delta}$. When the industry is fragile, this increase in the probability of default can be larger. More precisely, with probability λ it is the same as for the solid industry (i.e. $\underline{\Delta}$), but with probability $1 - \lambda$ it is $\bar{\Delta} > \underline{\Delta}$. The expected default rate under shirking in the fragile industry ($\lambda\underline{\Delta} + (1 - \lambda)\bar{\Delta}$) is denoted by $\hat{\Delta}$.[10] The unfolding of uncertainty within one period is represented in Figure 1.

To illustrate the effect of shirking in fragile and strong industries, consider the resecuritization

[10] One could set λ to zero, so that the probability of default under shirking would always be $\bar{\Delta}$, without major alterations to our results. As will be seen below, $\lambda > 0$ implies that, even when all managers shirk, the fragility of the industry may not be discovered immediately.

of loans. Our assumption means that when the technique is fragile (as it turned out to be the case for CDOs of ABS), there is a probability $1-\lambda$ that shirking (i.e. not exerting due diligence in the screening and monitoring of borrowers) will result in high default rates. By contrast, if the innovation is strong, shirking is less damaging. Thus, when the industry is fragile not only is it more exposed to negative shocks, but also it is more vulnerable to shirking.

Managerial effort is not observable by investors, and, when the manager does not exert effort, she obtains an unobservable private benefit from shirking, denoted by B. Hence, since managers have limited liability, there is a moral hazard problem.[11] The investor is the principal and the manager the agent. We assume

$$\underline{\Delta} Y > B.$$

which implies that it is socially optimal to exert effort to reduce default risk.

For simplicity we don't model the details of the activities of the innovative industry. Hence, although our modelling of that industry can be interpreted as a reduced form of the financial sector, we don't study explicitly financial intermediation or services to the traditional sector. This simplification enables us to concentrate on what is the main focus of our analysis: the agency relationship between investors and managers, the allocation of resources between the traditional sector and the innovative one, and the possibility of endogenous crises due to moral hazard.

2.3 Learning

All the agents in the economy observe returns realizations, and use these to conduct rational Bayesian learning about θ. At the first period ($t=1$), agents start with the prior probability, π_1 that $\theta=1$. For $t>1$, denote by π_t the updated probability that the innovative industry is strong, given the returns realized in the innovative sector at times $\{1,...,t-1\}$. While individual effort decisions are unobservable, aggregate outcomes reveal useful information. In particular, all investors and managers can tell whether there was a negative shock or not. Also, as can be seen in Figure 1, large aggregate default rates (i.e., $\bar{\Delta}$ or $\mu+\bar{\Delta}$) can only come from a fragile innovation. Thus the fragility of an innovation is detected for sure (and π_t goes to 0) when such high default rates are observed.

[11] As in Holmström and Tirole (1997) we cast the problem in terms of private benefits foregone by the manager when exerting effort. One could equivalently consider a model without private benefits but where effort would be costly.

When managers exert effort and there is no shock, all projects succeed at date t so that the probability that the industry is strong is revised upward to:

$$\pi_{t+1} = \frac{\bar{p}\pi_t}{\bar{p}\pi_t + \underline{p}(1-\pi_t)} > \pi_t. \tag{1}$$

On the other hand, if managers exert effort but there is a negative shock, a fraction μ of projects default. In that case the probability that the innovation is strong is revised downward to

$$\pi_{t+1} = \frac{(1-\bar{p})\pi_t}{(1-\bar{p})\pi_t + (1-\underline{p})(1-\pi_t)} < \pi_t.$$

If, in equilibrium, managers don't exert effort and there is no negative shock, the aggregate default rate is $\bar{\Delta}$ or $\underline{\Delta}$. $\bar{\Delta}$ reveals that the innovation is fragile. But, conditional on $\underline{\Delta}$, the probability that the industry is strong is updated to:

$$\pi_{t+1} = \frac{\bar{p}\pi_t}{\bar{p}\pi_t + \lambda\underline{p}(1-\pi_t)} > \pi_t. \tag{2}$$

This strong increase reflects that, in spite of shirking, the aggregate default rate was limited.

Similarly, if managers don't exert effort in equilibrium and there is a negative shock, the aggregate default rate is $\mu + \bar{\Delta}$ or $\mu + \underline{\Delta}$. The former reveals that the industry is fragile. But, if the aggregate default rate is $\mu + \underline{\Delta}$, the probability that the industry is strong is updated as in (2).

Hence, conditionally on a given level of effort, relatively high aggregate default rates lead to a decline in π_t, while relatively low default rates lead to an increase in π_t. As long as managers exert effort, π_t remains between 0 and 1. But, if shirking prevails, beliefs become more volatile: changes in the probability that the industry is strong are larger and can lead to $\pi_t = 0$.

2.4 Contracts

At time t, newly born investors and managers interact for one period. We assume they have access to the complete performance history of the industry. Hence they share the updated belief π_t.

First, consider the case where the contract incentivizes managers to exert effort. If there is no negative shock all projects should succeed and obtain Y. Therefore, if the output of the project run by manager i is equal to 0, while all others succeeded, it must be that manager i shirked. Hence it is optimal to set his compensation to 0. Even when there is a negative shock, it is also optimal (because of moral hazard and risk–neutrality), to set compensation to 0 in case of default.

Second, consider the case where the contract does not request managers to exert effort. In that case, only the expected compensation of managers matters, not its allocation across states. Hence, it is weakly optimal to compensate the manager only when the output of his firm is Y.

Accordingly, we consider contracts where managers are compensated only when their firm generates output Y. We denote the value of this compensation at time t by m_t, which can be interpreted as the bonus received by managers when they succeed.

3 Equilibrium when effort is observable

Consider first the benchmark case where effort is observable: Managers are instructed to exert effort and their compensation is set to clear the labor market. At time t, the expected output of firms operating in the innovative sector is:

$$S_t = [\pi_t(\bar{p} + (1 - \bar{p})(1 - \mu)) + (1 - \pi_t)(\underline{p} + (1 - \underline{p})(1 - \mu))]Y, \tag{3}$$

and the expected compensation of the managers is:

$$M_t = [\pi_t(\bar{p} + (1 - \bar{p})(1 - \mu)) + (1 - \pi_t)(\underline{p} + (1 - \underline{p})(1 - \mu))]m_t,$$

while investors obtain $S_t - M_t$ in expectation. Managers with types below M_t prefer to operate in the innovative sector. Hence, the supply of managers for that sector is:

$$G(M_t). \tag{4}$$

Investors with types below $S_t - M_t$ prefer to invest in the innovative one, and thus need to hire a manager. Hence, the demand for managers in the innovative sector is:

$$F(S_t - M_t). \tag{5}$$

Equating (4) and (5) the labor market–clearing condition is:

$$G(M_t) = F(S_t - M_t). \tag{6}$$

The supply of managers is continuous and increases from $G(0) = 0$ to $G(\bar{\nu}) = 1$, while the demand for managers is continuous and decreases from $F(S_t) > 0$ to 0. Consequently there exists a unique solution M_t^* to (6). In our simple model a natural measure of the size of the innovative sector is the number of managers, or equivalently the number of firms operating in that sector. Based on the discussion above, we state our first proposition (illustrated in Figure 2):

Proposition 1: *When effort is observable, the equilibrium expected compensation of managers in the innovative sector is M_t^* (the solution of (6)) and the size of that sector is $G(M_t^*)$.*

Suppose that at the beginning of period t, managers and investors expect the industry to be strong with probability $0 < \pi_t < 1$. If there is no negative shock during this period, then investors become more optimistic and the updated probability that the industry is strong goes up to $\pi_{t+1} > \pi_t$. Thus expected output in the innovative sector increases and the demand curve (5) goes up, while the supply curve (4) stays constant. Consequently, the equilibrium compensation of managers in period $t+1$ is $M_{t+1}^* > M_t^*$. In contrast, after a negative shock, the updated probability that the industry is strong goes down. Consequently the size of the innovative sector shrinks. These remarks are summarized in the following corollary:

Corollary 1: *Assume effort is observable. When there is no default, the size of the innovative sector goes up, along with the expected compensation of managers employed in that sector. When the aggregate default rate is $\mu > 0$, the size of the innovative sector and the expected compensation of managers both decline.*

Thus, in the benchmark case where effort is observable, learning generates fluctuations (good realizations lead to growth in the innovative sector, while bad realizations lead to decline), but there are no crises.

4 Equilibrium under moral hazard

4.1 Incentive compatibility

When effort is not observable but requested, we must impose the incentive compatibility condition that the manager prefers to exert effort rather than consuming private benefits, i.e.,:

$$\begin{aligned} & [\pi_t(\bar{p} + (1-\bar{p})(1-\mu)) + (1-\pi_t)(\underline{p} + (1-\underline{p})(1-\mu))]m_t \\ \geq \; & [\pi_t(\bar{p}(1-\underline{\Delta}) + (1-\bar{p})(1-\mu-\underline{\Delta})) + (1-\pi_t)(\underline{p}(1-\hat{\Delta}) + (1-\underline{p})(1-\mu-\hat{\Delta}))]m_t + B. \end{aligned}$$

This pins down the minimum incentive compatible bonus for the manager:

$$m_t \geq \frac{B}{\pi_t \underline{\Delta} + (1-\pi_t)\hat{\Delta}} = \frac{B}{\hat{\Delta} - \pi_t(\hat{\Delta} - \underline{\Delta})}.$$

This condition implies a minimum expected pay-off for the manager. Denote this minimum expected pay-off by R_t. We refer to it as the rent of the manager:

$$R_t = \frac{(1-\mu+\mu\underline{p}) + (\bar{p} - \underline{p})\mu\pi_t}{\hat{\Delta} - (\hat{\Delta} - \underline{\Delta})\pi_t} B. \tag{7}$$

The incentive compatibility condition can be rewritten as,

$$M_t \geq R_t, \tag{8}$$

which means that the expected compensation promised to the manager must be large enough to entice effort. The rent R_t that must be left to the manager varies with the beliefs (π_t) about the strength of the innovative sector. Since $\hat{\Delta} > \underline{\Delta}$, (7) implies that R_t increases with π_t. Because the strong industry is more robust to shirking than the fragile one, managers find shirking more tempting when they are confident that the industry is robust. Therefore, high rents are needed to provide incentives in that case.

Substracting the rent from the expected output yields the pledgeable income, i.e., the maximum expected revenue that can be pledged to the investors without compromising the incentives of the manager:

$$P_t = S_t - R_t. \tag{9}$$

Since both expected output and rents increase with π_t, the pledgeable income can be non–monotonic with the expected strength of the innovative sector. Relying on the above analysis, we obtain our next proposition.

Proposition 2: *When effort is not observable but requested, the pledgeable income $P(\pi_t)$ in the innovative sector is concave in π_t . Moreover if*

$$[(1-\mu+\mu\bar{p})\frac{\hat{\Delta}}{\underline{\Delta}}-(1-\mu+\mu\underline{p})]>\mu(\bar{p}-\underline{p})\frac{\Delta Y}{B}>(\frac{\underline{\Delta}}{\hat{\Delta}})^2[(1-\mu+\mu\bar{p})\frac{\hat{\Delta}}{\underline{\Delta}}-(1-\mu+\mu\underline{p})], \tag{10}$$

then the pledgeable income increases when π_t is close to 0 and decreases when π_t is close to 1.

As long as high returns are observed, confidence in the innovative sector increases. This boosts expected output, but it also raises rents. The marginal impact of increased confidence on pledgeable income decreases with π_t ($P(\pi_t)$ is concave). Moreover, under condition (10) pledgeable income is not monotonic in π_t. While initial improvements in confidence trigger an increase in pledgeable income, when high levels of confidence are reached, the increase in rent dominates the increase in expected surplus and pledgeable income decreases with π_t.

4.2 Equilibrium with effort

When effort is requested from the agent, there are two possible regimes, depending on whether the incentive compatibility condition binds or not. In the first regime, the market clearing condition determines the equilibrium compensation of the managers, as in the previous section, i.e.,

$$M_t = M_t^* \text{ s.t. } G(M_t^*) = F(S_t - M_t^*)$$

as in (6). For this to be the equilibrium, it must be that the incentive compatibility condition holds for M_t^*, i.e.,

$$M_t^* \geq R_t. \tag{11}$$

As illustrated in Figure 2, in this regime the supply and demand curves on the labour market intersect above R_t, so that the incentive compatibility condition does not bind.

In the second regime, as illustrated in Figure 3, the supply and demand curves on the labour market intersect below R_t. Thus, the incentive compatibility condition binds, i.e.,

$$M_t^* < R_t. \tag{12}$$

and the expected managerial compensation is

$$M_t = R_t. \tag{13}$$

Since this is above M_t^*, managers employed in the innovative sector earn greater expected compensation than in the observable effort case. Thus, although they are competitive, they earn rents. Such rents make working in the innovative sector very attractive. Indeed the number of managers who want to work in that sector is above the demand for their services, i.e.,

$$G(M_t) = G(R_t) > F(S_t - M_t).$$

Thus there is rationing in the labour market, as in the efficiency wage model of Shapiro and Stiglitz (1984).

For simplicity consider the case where ν is uniformly distributed over $[0, \bar{\nu}]$ and ρ is uniform over $[0, \bar{\rho}]$, i.e.,

$$G(\nu) = \frac{\nu}{\bar{\nu}}, F(\rho) = \frac{\rho}{\bar{\rho}}.$$

In that case the market clearing condition (6) defining M_t^* becomes:

$$\frac{M_t^*}{\bar{\nu}} = \frac{S_t - M_t^*}{\bar{\rho}}.$$

Thus:

$$M_t^* = \beta S, \tag{14}$$

where:

$$\beta = \frac{\bar{\nu}}{\bar{\nu} + \bar{\rho}} \in [0, 1].$$

The compensation of the manager is equal to a fraction (β) of the value created by the firm. This fraction reflects the relative values of the outside opportunities of managers and investors in the traditional sector. When the outside opportunities of managers, measured by their skills in the traditional sector, are high and the opportunities of the investors in that sector are poor, the market clearing compensation of the managers in the innovative sector is high.

The condition under which the incentive compatibility condition does not bind, (11), is equivalent to the condition that the pledgeable income be greater than the expected income of the investors in the first best

$$S_t - M_t^* \leq P_t. \tag{15}$$

After simple manipulations, this leads to the following proposition.

Proposition 3: *Consider the case where effort is not observable, but is requested and F and G are uniform.*

If

$$\frac{B}{\underline{\Delta}} < \beta Y, \tag{16}$$

then the incentive compatibility condition is not binding and the compensation of managers is set by the market clearing condition (6) as in the first best.

If

$$\frac{B}{\hat{\Delta}} < \beta Y < \frac{B}{\underline{\Delta}}, \tag{17}$$

there exists a threshold value $\bar{\pi} \in [0,1]$ such that, for $\pi_t \leq \bar{\pi}$ the incentive compatibility condition is not binding and the compensation of managers is set by the market clearing condition (6), while for $\pi_t > \bar{\pi}$, the compensation of managers is set by the incentive compatibility condition (13).

If

$$\beta Y < \frac{B}{\hat{\Delta}}, \tag{18}$$

the incentive compatibility condition always binds and the compensation of managers is set by the incentive compatibility condition (13).

Inequality (16) holds when the share of expected output that has to be left to managers in the first best is larger than what they must receive for incentives reason. This arises when $\frac{B}{\underline{\Delta} Y}$ is low, so that the moral hazard problem is not severe and induces no distortion in equilibrium. In this case, the expected net cashflow obtained by investors in the innovative sector is: $S_t - M_t^*$. When $\frac{B}{\underline{\Delta} Y}$ is large, inequality (16) does not hold and the agency problem is severe and the incentive compatibility condition can bind. Figure 4 illustrates what happens in that case when (17) holds. The figure illustrates that there exists a threshold $\bar{\pi}$ such that, when $\pi_t > \bar{\pi}$, the IC binds and the expected net cashflow obtained by investors in the innovative sector is: $S_t - R_t = P_t$.

4.3 Equilibrium without effort

Now turn to the case where effort is not requested from the agent in equilibrium. In that case the expected output from the project and the expected wage earned by the managers are given in the next lemma:

Lemma 1: *When there is no effort the expected output is*

$$\hat{S}_t = \{[1-\mu(1-\underline{p})-\hat{\Delta}] + \pi_t[\mu(\bar{p}-\underline{p}) + (\hat{\Delta}-\underline{\Delta})]\}Y,$$

and the expected wage earned by managers is

$$\hat{M}_t = \{[1-\mu(1-\underline{p})-\hat{\Delta}] + \pi_t[\mu(\bar{p}-\underline{p}) + (\hat{\Delta}-\underline{\Delta})]\}m_t.$$

When there is no effort in equilibrium, the demand for managers is: $F(\hat{S}_t - \hat{M}_t)$ while he supply of managers is: $G(\hat{M}_t + B)$. The market clearing expected wage without effort is $\hat{M}_t^*$ is such that

$$F(\hat{S}_t - \hat{M}_t^*) = G(\hat{M}_t^* + B).$$

Using this market clearing condition, the next proposition spells out the equilibrium wage arising in the uniform case when effort is not requested.

Proposition 4: *Assume F and G are uniform. If effort is not requested in equilibrium, then the labour market for managers clears, the expected compensation of managers is*

$$\hat{M}_t^* = \beta\hat{S}_t - (1-\beta)B,$$

and their total expected utility is $\beta(\hat{S}_t + B)$, while that of investors is $(1-\beta)(\hat{S}_t + B)$.

When effort is not exerted, the total expected value created by each firm is $\hat{S}_t + B$. Since the agent does not exert effort, no rent needs to be left to managers and the market clears. Thus the shares of the total value created obtained by managers and investors simply reflect their outside options in the traditional sector. Correspondingly, managers get a fraction β of $\hat{S}_t + B$ while investors get the complementary fraction.

4.4 Is there effort in equilibrium?

We now investigate if effort prevails in equilibrium. Consider a candidate equilibrium, where effort is requested. Could a pair manager–investor be better off by deviating to a contract which would not request effort? If there is no such profitable deviation, then effort is requested in equilibrium.

Symmetrically, consider a candidate equilibrium where effort is not requested. Could a pair manager–investor be better off by deviating to a contract that would request effort? Again, if there is no such profitable deviation, there exists an equilibrium without effort. The following proposition, illustrated in Figure 4, states the conditions on parameter values under which one of the candidate equilibria or the other prevails in the uniform case.

Proposition 5: *Consider the case where F and G are uniform and assume*

$$\{\beta + \frac{(1-\beta)^2\underline{\Delta}}{1-\mu(1-\bar{p})+(1-\beta)\underline{\Delta}}\}\underline{\Delta} < \frac{B}{Y} < \beta\hat{\Delta}.$$

Then there exists a threshold value $\hat{\pi} > \bar{\pi}$ such that effort is requested in equilibrium for $\pi_t \leq \hat{\pi}$, while equilibrium involves no effort for larger values of π_t.

The intuition behind the proposition is the following: As long as $\pi_t \leq \hat{\pi}$, the rents that must be left to the managers are sufficiently small that the pledgeable income is greater than the expected income investors would get if effort was not requested. So, for these values of π_t, investors prefer to request effort, and it is implemented in equilibrium. In contrast, for $\pi_t > \hat{\pi}$, the rents which must be left to managers to incentivize effort are so high that investors prefer to give up on incentives and allow for the greater default risk resulting from shirking. The resulting increase in risk is socially costly, it does not arise in equilibrium when effort is observable, but it may occur in presence of moral hazard.

5 Empirical implications and calibration of the model

In this section, we draw the empirical implications of our theoretical analysis for the financial industry. Note that our model is not relevant for all parts of the financial industry and all periods. It only applies to periods with significant innovations, uncertainty about the strength of these innovations and informational asymmetries between investors and managers. Thus, our model does not apply to standard banking activities during periods with little financial innovation, e.g., the 1950s or the 1960s, or financial innovations with no or limited information asymmetry.[12] In contrast, our model is relevant

[12] For example the securitization of standard (not subprime) bank loans is commonly viewed as a success. It started in 1968, when the GNMA created the passthrough security for mortgages guaranteed by the US government. It was later extended to broader classes of loans, including those guaranteed by Government Sponsored Entities (Fannie Mae and

to analyze the flow of financial innovations that took place at the beginning of this century, such as e.g., structured finance, hedge funds and private equity funds. It is also relevant for previous waves of financial innovations, with uncertainty and information asymmetry, such as, e.g., the stock market boom of 1920s, the growth of synthetic portfolio insurance in the early 1980s, or the development of junk-bonds markets from late 1970s until they crashed in the 1980s.

5.1 Risk taking, fat tails and endogenous crises

Fat tails in the model: As stated in Proposition 5, when π_t becomes greater than $\hat{\pi}$, the innovative industry switches to the risk-taking regime. Correspondingly, the distribution of default risk is distorted towards more failures. This implies that, after a series of successes, fat tails and crises can emerge endogenously. To see this compare the distribution of aggregate default rates for a relatively low value of π_t: $\pi^- < \hat{\pi}$ and a larger value of π_t: $\pi^+ > \hat{\pi}$. The former prevails when the innovative industry is new and has a short track record. The latter prevails when the innovative industry has been operating with success for several years. In the former case, the aggregate default rate is 0 with probability $\pi^-\bar{p} + (1-\pi^-)\underline{p}$ and μ with complementary probability. In the latter case, it is $\underline{\Delta}$ with probability $\pi^+\bar{p} + (1-\pi^+)\underline{p}\lambda$, $\bar{\Delta}$ with probability $(1-\pi^+)\underline{p}(1-\lambda)$, $\mu + \underline{\Delta}$ with probability $\pi^+(1-\bar{p}) + (1-\pi^+)(1-\underline{p})\lambda$ and, finally, $\mu + \bar{\Delta}$ with probability $(1-\pi^+)(1-\underline{p})(1-\lambda)$. Thus, when the probability that the innovative industry is strong is greater than or equal to π^+, very large aggregate default rate $\mu + \bar{\Delta}$ can be observed. Such fat tails in the distribution of aggregate risk do not arise when there is no moral hazard, since in that case risk–prevention effort is always exerted in equilibrium.

Calibration: The assumptions underlying our model are descriptive of salient features of the mortgage subprime industry : It relied on new techniques,[13] there was uncertainty about the strength

Freddie Mac) as well as more risky loans such as auto, credit card, commercial mortgage, student and business loans. It's likely that this financial innovation was not subject to major informational asymmetries. So far, it has been immune to crashes.

[13] These new techniques enabled the industry to i) attract new categories of borrowers previously denied access to credit (e.g., "low document loans" or "option mortgages") and ii) transfer risks (e.g., tranching). Brunnermeier (2009) offers an illuminating analysis of the "originate to distribute model."

of that industry,[14] and there was information asymmetry regarding the exact structure and content of the portfolios resulting from tranching. The stylized facts from that industry are in line with the properties of our equilibrium, in particular the boom and bust cycle (illustrated in Figure 5, borrowed from Jaffee 2008) and the emergence of fat tails and endogenous crises. To show this more precisely, we now calibrate tour model to match some statistics from the MBS industry.

The calibration is designed so that, during the bliss years of the "great moderation" (2002, 2003, 2004) managers exert effort and correspondingly aggregate default risk is between 0 and μ. As illustrated in Figure 6 (also borrowed from Jaffee 2008), for loans originated until 2004 subprime delinquency rates two years after origination were less than 10%. To match these observations, we set $\mu = 6\%$.

In line with the literature (e.g., Caballero and Krishnamurthy, 2009), we make the plausible assumption that there was no negative aggregate shock during the bliss years of the "great moderation" (from 2002 to 2005.) Also, we design the calibration so that equilibrium switches to the risk–taking regime (i.e. π_t reaches $\hat{\pi}$) in 2005. This switch rationalizes the finding by Demyanyk and Van Hemert (2008), that the decline in performance for loans made in 2005-2006 cannot be fully explained by observable composition effects (i.e. changes in the types of subprime loans and in observable borrower characteristics) or economic conditions, but reflects a decline in the quality standards of lenders. Furthermore, as pointed by Demyanyk and Van Hemert (2009), their empirical findings suggest that lenders were aware of the deterioration in loan quality. This is also what happens in our model.

In the risk–taking regime, aggregate default rates are between $\underline{\Delta}$ and $\mu + \bar{\Delta}$. Figure 6, shows that subprime delinquency rates two years after origination rose to around 12% for loans originated in 2005, and more than 20% for loans originated afterwards.[15] To match these observations, we set $\underline{\Delta} = 12\%$, $\bar{\Delta} = 22\%$.

Finally, we set i) $\beta = .5$, i.e., before rents the compensation of managers employed in the sector is 50% of the profits, which is in line with anecdotal evidence, ii) $\frac{B}{Y} = .077\%$, i.e., the private benefits from shirking are slightly lower than 8% of the potential profits of the institution, and iii) $\lambda = .6$, $\bar{p} = .8$, $\underline{p} = .2$. The latter three probabilities are key parameters of the Bayesian updating conducted by agents. These values of the parameters ensure that, after three years without negative shock (2002,

[14] In particular there was uncertainty about the probability of a nationwide drop in real–estate prices.

[15] The time pattern of default rates after one year is similar.

2003, 2004), confidence becomes so high that the equilibrium switches to the risk–taking regime in 2005.

For these parameter values, the distribution of aggregate default risk in the effort and risk–taking regimes generated by our model around the equilibrium switching point is depicted in Figure 7. The figure illustrates the shift of the distribution of aggregate defaults, and the fat tails of that distribution. The realization of the high default event, made possible by equilibrium shirking, corresponds to the occurrence of the endogenous crisis.

5.2 Managers' rents and investors' returns

Our model implies that during innovation waves, if the performance of the industry is initially good, it grows and attracts more and more skilled managers. At some point these managers earn rents, i.e., their pay exceeds the market clearing wage they would receive in a frictionless market. These rents arise in equilibrium, in spite of competition between managers, because of incentive constraints, in line with Shapiro and Stiglitz (1984). They lead to desequilibrium in the labor market, as the supply of would be finance managers exceeds the demand.

All these theoretical results are consistent with the empirical findings of Philippon and Reshef (2008). They observe that during the 1920s and after the 1990s, there was a burst of financial innovation accompanied by an increase in the complexity of jobs and skills and managers' pay in the finance sector. They find evidence of rents in the financial industry, associated with involuntary unemployment in that sector.

Another implication of our model is that, when there is a series of successful years (without negative aggregate shocks), one will simultaneously observe i) an increase in the amount of funds invested (due to increased confidence) and ii) a decline in the investors' net returns from these investments (due to the growth in rents.) This, in turn, implies that time–weighted average returns will be larger than than money–weighted ones. Indeed, since the amount of funds invested increases, time–weighted returns place relatively more weight on early years (which have greater realized net returns) than money–weighted ones. This is in line with the recent empirical finding by Dichev and Yu (2010) that, for investors in hedge funds, dollar weighted returns are 3 to 7 percent lower than corresponding buy–and–hold fund (time weighted) returns.

6 Conclusion

This paper offers a theory of the dynamics of innovative industries based on two key assumptions: i) new industries are not well known, and therefore learning will be conducted about the strength of these innovations, ii) in such industries it is difficult for outsiders to understand and monitor managers' actions, and therefore there is moral hazard. These assumptions are in line with major features of financial innovations waves, especially that of the early 2000s. Our theory shows how moral hazard can lead to endogenous crises and fat tails in the distribution of aggregate default. A calibration of our model generates figures in line with stylized facts from the recent boom and bust cycle in the finance sector.

Our theory thus uncovers fundamental economic forces implying that innovation waves raise the risk of endogenous crises. It also delivers several policy implications. Large rents offer an early signal that systemic risk is rising. Information asymmmetry, which is at the root of endogenous crises, should be mitigated by increased transparency, in markets (e.g., exchanges versus OTC) or in the disclosure of positions and trades (e.g., to CCPs). Policy intervention to increase transparency is especially valuable when initially successful innovations lead to high confidence and large rents.

Proofs:

Proof of Proposition 2:

The pledgeable income is:

$$P(\pi_t) = [(1-\mu+\mu\underline{p}) + (\bar{p}-\underline{p})\mu\pi_t]Y - \frac{(1-\mu+\mu\underline{p}) + (\bar{p}-\underline{p})\mu\pi_t}{\hat{\Delta} - \pi_t(\hat{\Delta} - \underline{\Delta})}B.$$

Its first derivative with respect to π_t is

$$P'(\pi_t) = \mu(\bar{p}-\underline{p})Y - \frac{(\bar{p}-\underline{p})\mu\hat{\Delta} + (1-\mu+\mu\underline{p})(\hat{\Delta}-\underline{\Delta})}{[\hat{\Delta} - \pi_t(\hat{\Delta} - \underline{\Delta})]^2}B.$$

That is

$$\mu(\bar{p}-\underline{p})Y - \frac{(1-\mu+\mu\bar{p})\hat{\Delta} - (1-\mu+\mu\underline{p})\underline{\Delta}}{[\hat{\Delta} - \pi_t(\hat{\Delta} - \underline{\Delta})]^2}B.$$

Note that

$$(1-\mu+\mu\bar{p})\hat{\Delta} - (1-\mu+\mu\underline{p})\underline{\Delta} > 0$$

because $\hat{\Delta} > \underline{\Delta}$ and $\bar{p} > \underline{p}$.

The second derivative is:

$$P''(\pi_t) = -2\pi_t(\hat{\Delta} - \underline{\Delta})\frac{(1-\mu+\mu\bar{p})\hat{\Delta} - (1-\mu+\mu\underline{p})\underline{\Delta}}{[\hat{\Delta} - \pi_t(\hat{\Delta} - \underline{\Delta})]^3}B < 0.$$

Now

$$P^{'}(1) = \mu(\bar{p}-\underline{p})Y - \frac{(1-\mu+\mu\bar{p})\hat{\Delta} - (1-\mu+\mu\underline{p})\underline{\Delta}}{\underline{\Delta}^2}B.$$

Thus, $P'(1) < 0$ if and only if

$$\mu(\bar{p}-\underline{p})Y < \frac{(1-\mu+\mu\bar{p})\hat{\Delta} - (1-\mu+\mu\underline{p})\underline{\Delta}}{\underline{\Delta}^2}B.$$

Furthermore

$$P'(0) = \mu(\bar{p}-\underline{p})Y - \frac{(1-\mu+\mu\bar{p})\hat{\Delta} - (1-\mu+\mu\underline{p})\underline{\Delta}}{\hat{\Delta}^2}B.$$

Thus, $P'(0) > 0$ if and only if

$$\mu(\bar{p} - \underline{p})Y > \frac{(1 - \mu + \mu\bar{p})\hat{\Delta} - (1 - \mu + \mu\underline{p})\underline{\Delta}}{\hat{\Delta}^2} B.$$

Hence, $P'(0) > 0$ and $P'(1) < 0$ if:

$$\frac{(1 - \mu + \mu\bar{p})\hat{\Delta} - (1 - \mu + \mu\underline{p})\underline{\Delta}}{\underline{\Delta}^2} B > \mu(\bar{p} - \underline{p})Y > \frac{(1 - \mu + \mu\bar{p})\hat{\Delta} - (1 - \mu + \mu\underline{p})\underline{\Delta}}{\hat{\Delta}^2} B.$$

That is

$$[(1 - \mu + \mu\bar{p})\frac{\hat{\Delta}}{\underline{\Delta}} - (1 - \mu + \mu\underline{p})] > \mu(\bar{p} - \underline{p})\frac{\underline{\Delta}Y}{B} > (\frac{\underline{\Delta}}{\hat{\Delta}})^2[(1 - \mu + \mu\bar{p})\frac{\hat{\Delta}}{\underline{\Delta}} - (1 - \mu + \mu\underline{p})].$$

QED

Proof of Proposition 3:

Substituting the market clearing managerial compensation (14) into (15), we obtain that the condition under which the incentive compatibility condition does not bind is $(1 - \beta)S_t \leq P_t$,that is:

$$\begin{aligned} & (1 - \beta)[(1 - \mu + \mu\underline{p}) + (\bar{p} - \underline{p})\mu\pi_t]Y \\ \leq \; & [(1 - \mu + \mu\underline{p}) + (\bar{p} - \underline{p})\mu\pi_t]Y - \frac{[(1 - \mu + \mu\underline{p}) + (\bar{p} - \underline{p})\mu\pi_t]B}{\hat{\Delta} - \pi_t(\hat{\Delta} - \underline{\Delta})}. \end{aligned}$$

Simplifying both sides by $[(1 - \mu + \mu\underline{p}) + (\bar{p} - \underline{p})\mu\pi_t]$ and rearranging, we obtain

$$\beta Y \geq \frac{B}{\hat{\Delta} - \pi_t(\hat{\Delta} - \underline{\Delta})}. \tag{19}$$

As π_t goes from 0 to 1, the right–hand–side of (19) increases from $\frac{B}{\hat{\Delta}}$to $\frac{B}{\underline{\Delta}}$.Hence, if

$$\beta Y \geq \frac{B}{\underline{\Delta}}. \tag{20}$$

then the incentive compatibility condition never binds, if

$$\beta Y < \frac{B}{\hat{\Delta}}, \tag{21}$$

it always binds, and if

$$\frac{B}{\hat{\Delta}} < \beta Y < \frac{B}{\underline{\Delta}}, \tag{22}$$

then there exists a threshold value of π_t, strictly between 0 and 1, such that the IC does not bind if and only if π_t is below this threshold.

QED

Proof of Lemma 1:

The proof stems directly from the computation of the probability that output Y will be generated when there is no effort:

$$[\pi_t(\bar{p}(1-\underline{\Delta}) + (1-\bar{p})(1-\mu-\underline{\Delta})) + (1-\pi_t)(\underline{p}(1-\hat{\Delta}) + (1-\underline{p})(1-\mu-\hat{\Delta}))].$$

After some manipulations, this simplifies to

$$[\pi_t(1-\mu-\underline{\Delta}+\mu\bar{p}) + (1-\pi_t)(1-\mu-\hat{\Delta}+\mu\underline{p}))],$$

which in turn simplifies to

$$[1-\mu(1-\underline{p})-\hat{\Delta}] + \pi_t[\mu(\bar{p}-\underline{p}) + \pi(\hat{\Delta}-\underline{\Delta})].$$

QED

Proof of Proposition 5:

The preliminary step of the proof is to compare the following three quantities, which are all functions of π_t: $(1-\beta)S_t$, $(1-\beta)(\hat{S}_t+B)$ and P_t. Note the following:

- $(1-\beta)S_t$ and $(1-\beta)(\hat{S}_t+B)$ are linear and increasing in π_t, and $\underline{\Delta}Y > B$ implies that $(1-\beta)S_t > (1-\beta)(\hat{S}_t+B)$.
- $\frac{B}{Y} < \beta\hat{\Delta}$ implies that, $P(\pi_t = 0) > (1-\beta)S(\pi_t = 0)$.
- $P(\pi_t = 1) < (1-\beta)[S(\pi_t = 1) + B]$ is implied by $\{\beta + \frac{(1-\beta)^2\underline{\Delta}}{1-\mu(1-\bar{p})+(1-\beta)\underline{\Delta}}\}\underline{\Delta} < \frac{B}{Y}$.

The functions $(1-\beta)S_t$, $(1-\beta)(\hat{S}_t+B)$ and P_t are plotted in Figure 4. As can be seen in the figure, there exists a pair of probabilities $\bar{\pi} < \hat{\pi}$ such that

$$P(\pi) > (1-\beta)S, \forall\pi < \bar{\pi}$$

and

$$P(\pi) < (1-\beta)(\hat{S}+B), \forall \pi > \hat{\pi}.$$

The remainder of the proof consists in three steps, each one considering a candidate equilibrium and spanning the different possible values of π_t.

First, we consider the case where $\pi_t < \bar{\pi}$. Consider the case where effort is requested. Since $\pi_t < \bar{\pi}$, the incentive compatibility condition does not bind, we are at the first best and there is no scope for deviations to no effort. Consequently, for $\pi_t < \bar{\pi}$, there is an equilibrium with effort.

Second, turn to the case where $\hat{\pi} > \pi_t > \bar{\pi}$. As above consider the candidate equilibrium where effort is requested. The investor receives P_t and the manager R_t. The sum of the two is S_t. Could a manager and an investor both prefer to deviate to a contract with effort? In that deviation, the total value created by the firm would be $\hat{S}_t + B$. Under our assumptions, this is lower than the total value created in the candidate equilibrium, S_t. Hence, the investor could not both agree to such the deviation. Consequently, for $\hat{\pi} > \pi_t > \bar{\pi}$, there is an equilibrium with effort.

Third, focus on the case where $\pi_t > \hat{\pi} > \bar{\pi}$. Consider a candidate equilibrium with effort. In that candidate equilibrium, in the innovative sector, managers would receive R_t while investors would obtain P_t. Would an investor be better off deviating to no effort? This deviating investor could hire a manager from the traditional sector. The cheapest of these managers would be the marginal one, with type $\nu = G^{-1}(F(P_t)) = \frac{\beta}{1-\beta}P_t$. Hiring this manager to implement the project without effort, the investor would obtain $\hat{S}_t + B - \frac{\beta}{1-\beta}P_t$. This is profitable for the investor if that leads to greater expected profits for her, i.e., if

$$\hat{S}_t + B - \frac{\beta}{1-\beta}P_t \geq P_t.$$

That is $(1-\beta)(\hat{S}_t + B) \geq P_t$,which holds by construction for $\pi_t \geq \hat{\pi}$. Hence, effort cannot prevail in equilibrium. Now, consider a candidate equilibrium without effort. The investor receives $(1-\beta)\hat{S}_t$ and the manager $\beta\hat{S}_t$. Could a manager and an investor both prefer to deviate to a contract with effort? In that deviation, the investor could at most get P_t. By construction, $P(\pi_t) < (1-\beta)\hat{S}_t$, hence, the investor could not agree to such a deviation. Consequently, for $\pi_t > \hat{\pi}$, there is an equilibrium without effort.

QED

References:

Barbarino, A., and B. Jovanovic, 2007, "Shakeouts and market crashes," *International Economic Review*, 385–420.

Berk, J., and R. Green, 2005, "Mutual fund flows and performance in rational markets," *Journal of Political Economy.*

Bergemann, D., and U. Hege, 1998, "Dynamic Venture Capital Financing, Learning and Moral Hazard," *Journal of Banking and Finance*, 703-735.

Bergemann, D., and U. Hege, 2005, "The financing of innovation: learning and stopping," *Rand Journal of Economics*, 719-752.

Brunnermeier, M., 2009, "Deciphering the Liquidity and Credit Crunch 2007–2008," *Journal of Economic Perspectives*, 77–100

Caballero, Ricardo and Arvind Krishnamurthy. 2008. "Collective Risk Management in a Flight to Quality Episode." *Journal of Finance.* 63(5): 2195-2236.

Caballero, Ricardo and Arvind Krishnamurthy. 2009. "Global imbalances and financial fragility." *American Economic Review, Papers and proceedings.*

DeMarzo, P., and Y. Sannikov, 2008, "Learning in Dynamic Incentive Contracts" Working paper, Stanford University.

DeMarzo, P., R. Kaniel and I. Kremer, 2007, "Technological Innovations and Real Investment Booms and Busts", *Journal of Financial Economics*, 85(3): 735-754

Demyanyk, Y., and O. Van Hemert, 2009, "Understanding the Subprime Mortgage Crisis", *Review of Financial Studies.*

Dichev, I., and G. Yu. 2010. "Higher Risk, Lower Returns: What Hedge Fund Investors Really Earn." forthcoming *Journal of Financial Economics.*

Edmans, A. and X. Gabaix, 2009, "Is CEO Pay Really Inefficient? A Survey of New Optimal Contracting Theories", forthcoming *European Financial Management Journal.*

He, Z. and A. Krishnamurthy, 2008, "A Model of Capital and Crises", Working Paper, Northwestern University.

Holmstrom, B., and J. Tirole, 1997, "Financial intermediation, loanable funds and the real sector," *Quarterly Journal of Economics*, 663–692.

Jaffee, D., 2008, "The US Subprime Mortgage Crisis: Issues Raised and Lessons Learned." Commission on Growth and Development Working Paper n^0 28, Washington DC.

Lorenzoni, G., 2008, "Inefficient credit booms," *Review of Economic Studies*, 809–833.

Pastor, L., and P. Veronesi, 2006, "Was there a Nasdaq bubble in the late 1990's ?," *Journal of Financial Economics.*, 81, 161–100.

Philippon, T., 2008, "The evolution of the US financial industry from 1860 to 2007: Theory and evidence," Working paper, New York University.

Philippon, T., and A. Reshef, 2008, "Skill biased financial development: education, wages and occupations in the U.S. financial sector", Working paper, New York University.

Rajan, R., 2006, "Has Financial Development Made the World Riskier?", *European Financial Management* 12: 499.

Rajan, U., A. Seru, and V. Vig, 2008, "The Failure of Models that Predict Failure: Distance, Incentives and Defaults," Working paper, University of Michigan at Ann Arbor.

Ramadorai, T., 2008, "The secondary market for hedge funds and the closed hedge fund puzzle.", Working paper, Saïd Business School, Oxford University.

Rob, R., 1991, "Learning and capacity expansion under demand uncertainty." *Review of Economic Studies*, 655–677.

Shapiro, C. and J. Stiglitz, 1984, "Equilibrium Unemployment as a Worker Discipline Device," *The American Economic Review*, 74, 433 – 444.

Zeira, J., 1987, "Investment as a process of search." *Journal of Political Economy*, 204–210.

Zeira, J., 1999, "Informational overshooting, booms and crashes." *Journal of Monetary Economics*, 237–257.

Figure 1: The structure of uncertainty in period *t*

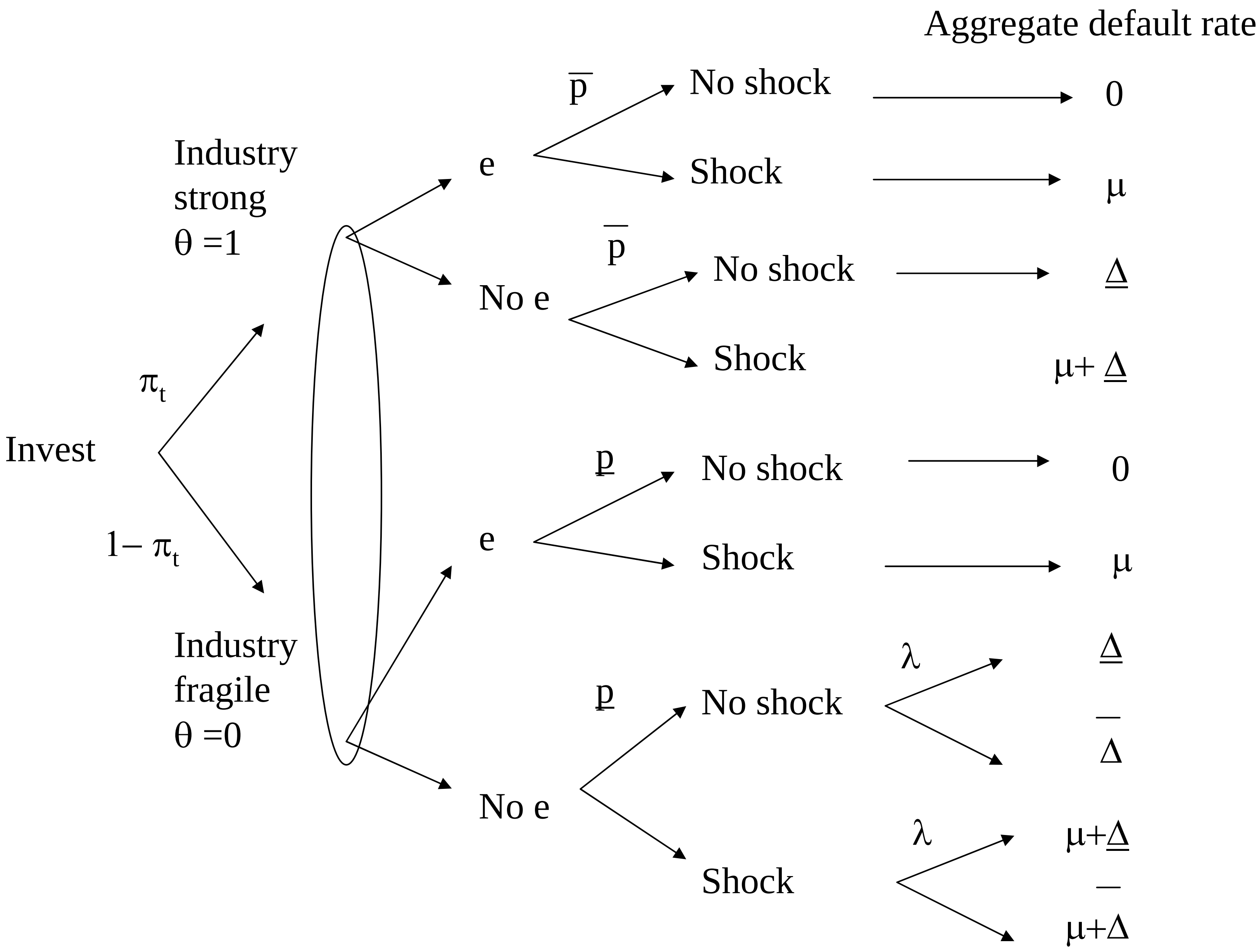


Figure 2: Supply, demand & rents when there is no rationing

M_t is the expected compensation of the manager. $G(M_t)$ is the mass of managers who, given this compensation, prefer to work in the speculative sector, and $F(S_t\text{-}M_t)$ the mass of investors who also choose that sector. M_t^* is the market clearing expected compensation and R_t the rent which must be left to managers to incentivize effort. When Mt* > Rt there is no rationing.

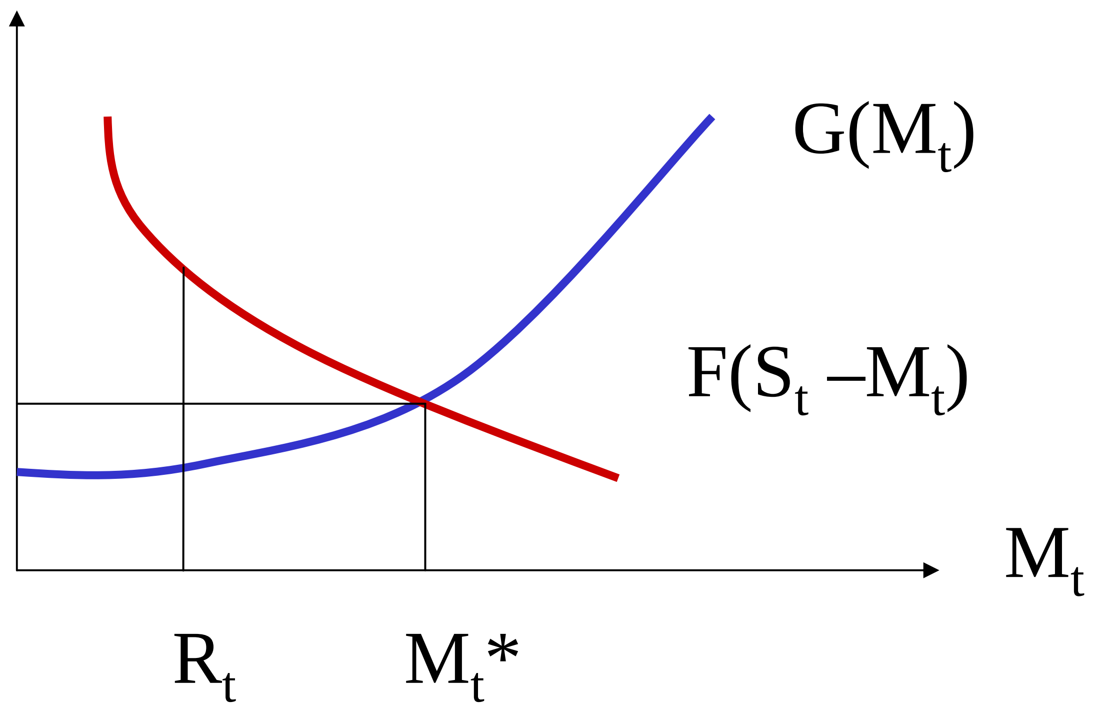


Figure 3: Supply, demand & rents with rationing

M_t is the expected compensation of the manager. $G(M_t)$ is the mass of managers who, given this compensation, prefer to work in the speculative sector, and $F(S_t\text{-}M_t)$ the mass of investors who also choose that sector. M_t* is the market clearing expected compensation and R_t the rent which must be left to managers to incentivize effort. When Mt* < Rt there is rationing.

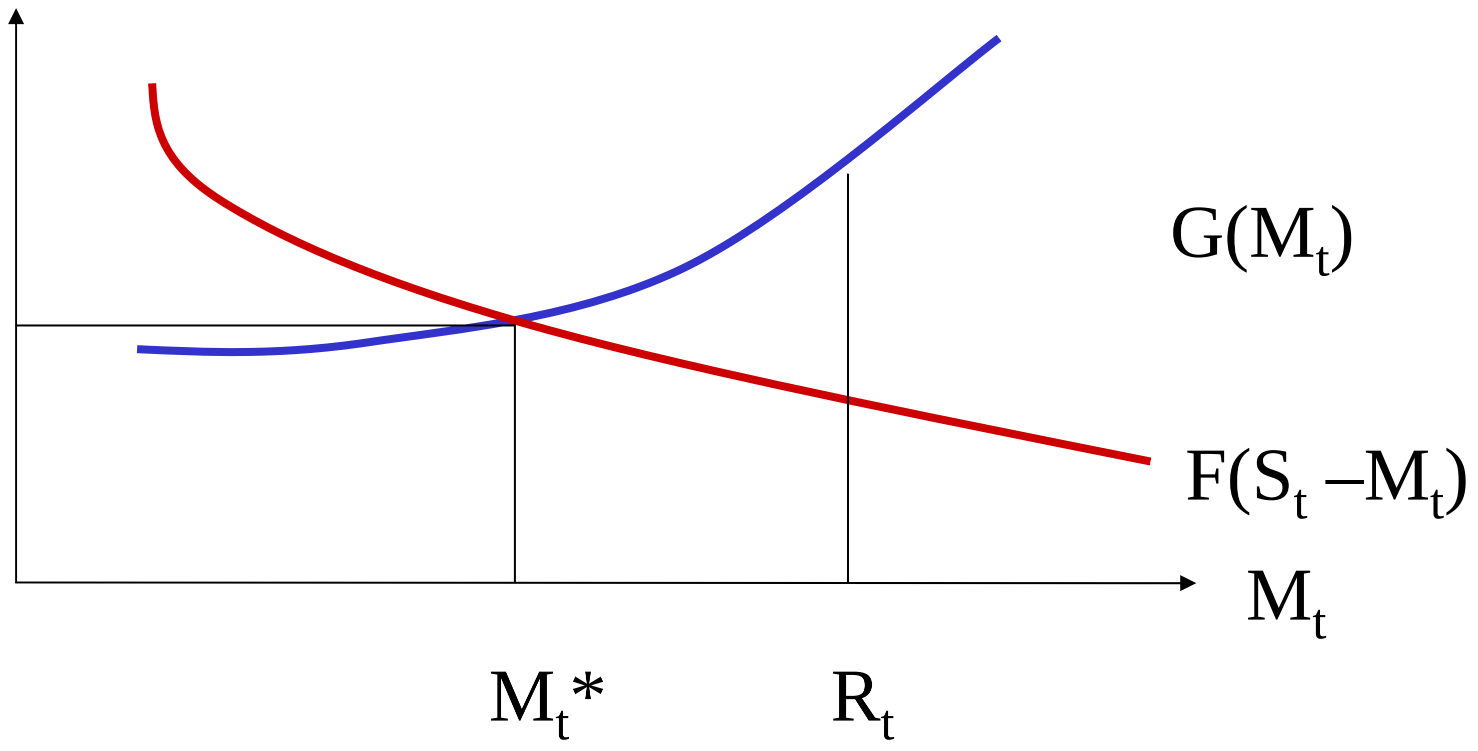
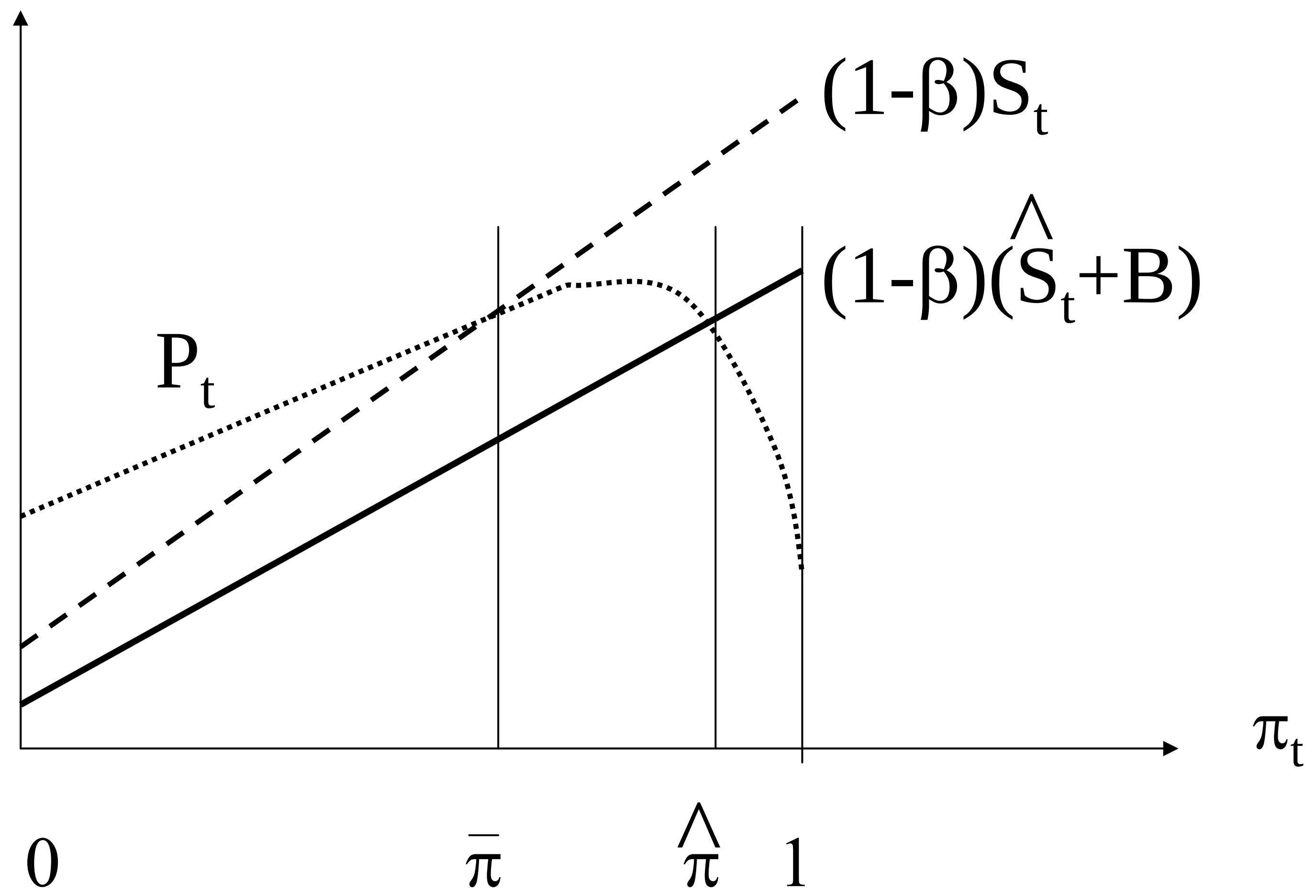
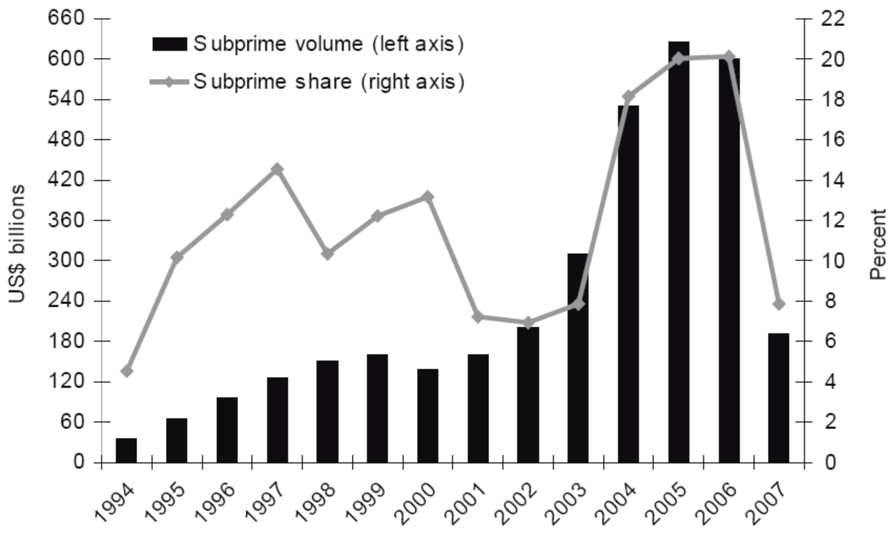


Figure 4: Pledgeable income & expected profit

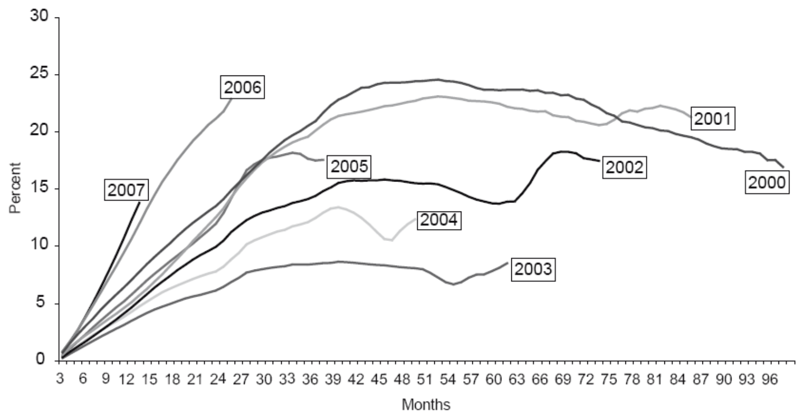
P_t is the pledgeable income. $(1-\beta)S_t$ is the equilibrium expected profit of investors if IC does not bind and effort is exerted. $(1-\beta)(\hat{S}_t+B)$ is the expected profit of investors without effort.





Source: *Inside Mortgage Finance*.

Figure 5: Subprime Mortgage Originations, Annual Volume and Percent of Total



Source: Source: LoanPerformance (LP) data from First American CoreLogic.

Figure 6: Subprime Delinquency Rate 60+ Days, By Age and Year of Origination

Figure 7: The distribution of aggregate default rates

The histogram plots the distribution of aggregate default rates in the calibration. On the horizontal axis are the different possible aggregate default rates in equilibrium. On the vertical axis are the probabilities of these different equilibrium outcomes. The two bars on the left correspond to the outcomes in the effort regime. The four bars on the right are the outcomes in the risk-taking regime.