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BANKS' RISK RACE: A SIGNALING EXPLANATION

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Abstract

Many observers argue that the abnormal accumulation of risk by banks has been one of the major causes of the 2007-2009 financial turmoil. But what could have pushed banks to engage in such a risk race? The answer brought by this paper builds on the classical signaling model by Spence. If banks' returns can be observed while risk cannot, less efficient banks can hide their type by taking more risks and paying the same returns as the efficient banks. The latter can signal themselves by taking even higher risks and delivering bigger returns. The game presents several equilibria that are all characterized by excessive risk taking as compared to the perfect information case.

Keywords: Banking sector, Risk strategy, Risk/return tradeoff, Signaling, Imperfect information.
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1 Introduction

The 2007-2009 financial crisis has been by all dimensions one of the most severe since the Great Depression (Brunnermeier, 2009). Social costs are huge, both in terms of output loss or rising unemployment. Public deficits crossed limits unthinkable a few years ago and, within the next three years public debt is expected to reach the level of annual GDP in many developed countries. While scholars will debate for many years about the contribution of different factors to this crisis, there is one point on which a majority of experts tend to agree: to a large extent, this crisis was brought about by an abnormal accumulation of risk by banks (Borio, 2008; Trichet, 2008; Diamond and Rajan, 2009). This observation begs the question on why, in the first place, did banks engage in what can be described as a genuine race for risk?

The answer provided in this paper builds on the classical signaling model by Spence (1973; 2002). One key feature of banking activity is put forward by Morgan (2002, p.874), who claims that "risks taken into the process of intermediation are hard to observe from outside the banks".[1] Indeed, banks are traditionally very reluctant to disclose any information about their clients on both sides of their balance sheets. Furthermore, the composition of their asset portfolio is both a strategic decision and a key factor of success; no bank will eagerly disclose this information.[2] Over the last twenty years, the complexity (and the opacity) of banks' financial intermediation increased dramatically, being driven essentially by a shift from the traditional "deposit and loan" model to the "orginate-to-securitize" model (Diamond and Rajan, 2009). In theory, securitization should have allowed banks to transfer most of the credit risk to a myriad of investors; in practice, recent data show that US banks used to hold large amounts of high risk securities on their books; furthermore, during the crisis, they had to cover the risks carried by off-balance sheet entities they had created for securitization purposes. European banks have also aggressively invested in MBSs and CDOs with a hidden content in US subprime loans, that had a true risk known only to

[1] See also Langohr and Langohr (2008).

[2] Should a bank decide to disclose its full exposure to risk, this could not be done instantaneously. In 2009, the government-led stress tests that aimed to measure the US banks resilience to simulated additional shocks, required several months to be completed. But by the time the results are published, the balance sheet composition may have changed.

a minority of insiders. Hence, while bank returns are disclosed every quarter, the structural risk taken by a bank is much harder to assess.

In general, given that higher risks command higher returns, banking technology allows the manager to choose the preferred risk/return combination. As the experience of this crisis has shown, banks are not equally equipped to face adversity. The list of losers is as long as the list of winners.[3] Actually, banks differ in their portfolio of activities, investment and loan opportunities, risk management systems and operating costs. In this paper we focus on the latter, and assume that there are only two types of banks, the highly efficient (or good) ones and the less efficient (or bad) ones. A less efficient bank can deliver the same returns as an efficient bank only if it takes more risks on its balance sheet.

We analyze banks' risk/return strategies within the framework of a signaling game that opposes banks' managers to shareholders. In a perfect information world, all investors would flee the less efficient banks to join the most efficient ones, and the former type of bank would be pulled out of the market. However, if returns can be observed by investors but risk cannot, then less efficient banks would survive if they manage to conceal their type. They can do so by increasing the amount of risk in order to deliver the same returns as the high efficient banks. However, if regulation sets an upper limit on the amount of risk that a bank can take, than good banks can signal themselves by increasing returns (and risk) up to the point where bad banks cannot follow them.

We will show that the game presents several types of equilibria, depending on the on the proportion of good banks and operating costs. The main contribution of the paper is to emphasize that, under imperfect information, in any equilibrium banks have no other optimal choice than holding more risk than the perfect information or efficient amount of risk. Furthermore, for some parameter values, we get a typical configuration of multiple equilibria; which one of them actually materializes ultimately depends on investors' beliefs.

The paper is organized as follows. The next section introduces our main assumptions, Section 3 analyzes the equilibria of the game, Section 4 presents our conclusions.

[3] The dramatic fall of Lehman Borhers, or the massive support of the respective governements to rescue Citigroup, UBS, Dexia or Northern Rock, etc. should be weighted against rather successful stories of Barclays, Nomura, Santander, Goldman Sachs, JP Morgan Chase, and so on.

2 Main assumptions

The model is cast as a game between banks' managers and shareholders. The banking sector is made up of publicly listed banks, that take deposits and issue debt in order to grant loans and buy financial assets. If the bank has access to a risk-free asset and to a portfolio of risky assets and loans, the manager can pick any combination of risk/return along the capital market line, a tangent to the efficient frontier (Markowitz, 1952). A higher return can be obtained only if the bank takes more risks (by investing more in the efficient portfolio of risky assets and loans).

Denoting the net return by R and the amount of risk by v, this typical trade-off between risk and return for a bank of type i can be written:

$$R^i(v) = R_0 + \theta v - c^i, \tag{1}$$

where $R_0 > 0$ is the interest rate of the risk-free asset, $\theta > 0$ is the slope of the capital market line and c^i stands for the bank-specific operating cost.[4] The inverse function, indicating the risk needed to achieve a given return for a bank with operating cost c^i is also of interest for further developments:

$$v^i(R) = \theta^{-1}\left[R - R_0 + c^i\right]. \tag{2}$$

We assume that, depending on the quality of their management, banks differ in their operating costs.[5] To keep the model as simple as possible, we assume that banks can be of two types: good banks (of type g) with a low operating cost c^g that can be normalized to zero without loss of generality and bad banks (of type b) with a high operating cost $c^b = c > 0$. In Figure 1, we represent the capital market lines of such a good and bad bank. It can be noticed that in order to provide shareholders the same net return, bad banks must take riskier bets, that is $v^b(R) > v^g(R)$, $\forall R > R_0$.

Let q be the proportion of good banks in the total population of banks, $1 - q$ being the proportion of bad banks. This distribution of banks is common knowledge.

[4] Financial literature focuses on return variance (denoted often by σ^2) as a proxy for risk. The risk considered in this text is of the nature of an extreme event. The impact of such event on the firm cannot be directly inferred from the observed return variance.

[5] The structure of the problem and the solution would not change if, instead of different operating costs, we assume that banks differ in their investment opportunities (thus, the Markovitz frontier would be broader for the stronger bank, and the slope of its capital market line would be steeper than for the weaker bank).

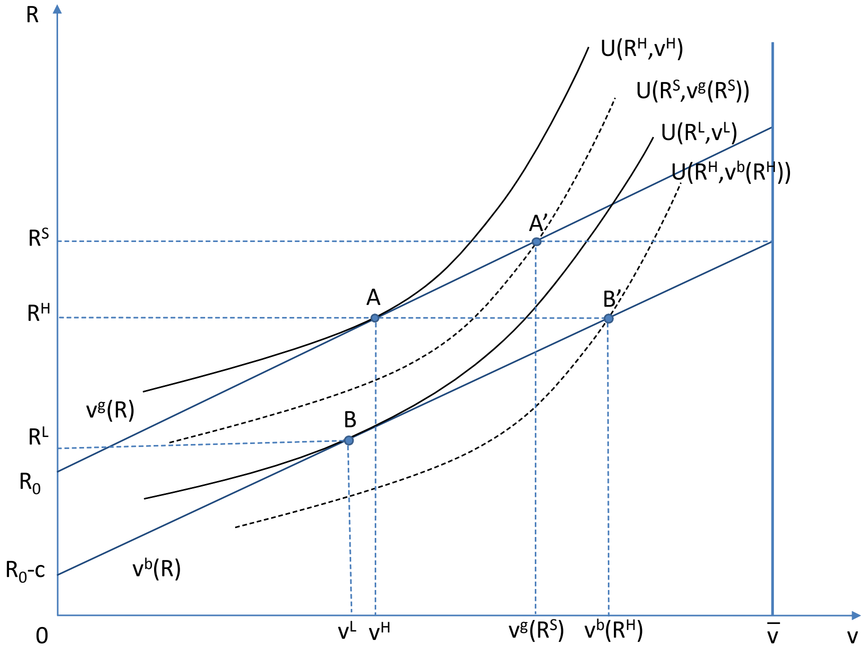

Figure 1: Return strategies, risk and utilities

In a general form, we represent the utility of the representative risk-averse shareholder's by a quasiconcave function $U(R, v)$, with $\partial U(,)/\partial R > 0$, $\partial U(,)/\partial v < 0$. Resulting indifference curves are convex.

Shareholders agree to pay the bank's manager a compensation that is proportional to their perceived utility, or $W = \gamma E[U(R, v)]$, where $E[-]$ is the expectations operator;[6] the compensation factor γ is not essential, so we normalize it to 1.

Under these assumptions, in a perfect information set-up, a manager running a good bank would simply choose the bundle (R^H, v^H) that maximizes his income given the bank's capital market line, such as indicated at point A in Figure 1.

Notice that the manager of a bad bank would prefer the bundle (R^L, v^L), at point B in the same figure. Yet, given that shareholders' satisfaction is higher for good banks than for bad banks, no investor would hold the bad bank stocks: therefore less efficient banks cannot survive in this perfect information world.

However, the assumption of perfect information is not very realistic given that a bank's risk

[6] These expectations will be determined over the set of beliefs about the type of bank given the return strategy.

exposure is a very complex commodity. As noticed in the Introduction, it is very difficult for outsiders, even for expert ones, to evaluate the full amount of risk taken by a bank. Building on these basic fact, we further assume that the level of risk exposure of a given bank is private information to its manager, while the stock return is public information. In this context the set of strategies of the banks is more sophisticated:

- For bad banks, like in the perfect information set-up, the strategy of playing R^L is never optimal since it reveals the type of the bank and all the shareholders would leave it. At difference with the perfect information case, in the imperfect information environment a bad bank can survive if it manages to conceal its type. It can reach this outcome by increasing the riskiness of its portfolio such as to deliver the return R^H, i.e. the perfect information return of the good bank (at point B' in Figure 1).

- Good banks can play their perfect information optimal strategy R^H as well. However, if good banks want to make sure that no bad bank has an incentive to imitate them, they should pay a sufficiently high return that a bad bank cannot deliver it. Let us assume that the existing regulation sets an upper limit on the total risk allowed to be taken by any bank, denoted by $\bar{v}$ (the vertical line on Figure 1). Limits on a bank's leverage should have this effect.[7] Then, for sure, if the good bank pays a return slightly above R^S, defined by:

$$R^S = R_0 + \theta \bar{v} - c, \tag{3}$$

  it signals itself as a good bank given that bad banks cannot further increase their risk to copy them. R^S is thus the second return strategy of the good bank.

Turning now to the manager's payoff, we argued that if investors perceive that a bank is of the bad type, this bank leaves the market and the compensation of the manager becomes zero. So, a positive compensation for the manager can be defined only for banks that stay on the market (i.e., they are not perceived as being bad banks). Denoting by $\Pr[i|R^j]$ the probability

[7] According to the Bale I regulation, banks should hold 8% of their loans on their balance sheets. Bale II regulation in force in Europe since 2007, tried to link capital requirements to other assets and off-balance sheet entities (Brunnermeier, 2009).

shareholders assign to the event that a bank is of the type $i \in \{b, g\}$ if the return strategy is R^j, with $j \in \{L, H, S\}$, the manager's payoff can be written:

$$W(R^j) = \begin{cases} 0 \text{ if } \Pr[b|R^j] = 1 \\ \Pr[g|R^j]U(R^j, v^g(R^j))] + \Pr[b|R^j]U(R^j, v^b(R^j)), \text{ if } \Pr[b|R^j] \in [0, 1[\end{cases} \tag{4}$$

Notice that return strategies R^S and R^L reveal perfectly a bank's type. Thus $W(R^S) = U(R^S, v^g(R^S))$ and $W(R^L) = 0$.

The typical *sequence of decisions* goes like this:

- At step 0, Nature picks the type of bank, either b or g.
- At step 1, depending on their type, banks chose their return strategy.
- At step 2, shareholders make their opinion about the type of bank given the observed returns and pay the manager a compensation proportional to their own expected utility; the game ends.

Finally, we notice that the gap between $U(R^S, v^g(R^S))$ and $U(R^H, v^b(R^H))$ depends on the operating cost c. Figure 2 shows that there is a $\tilde{c}$ such that $U(R^S, v^g(R^S)) = U(R^H, v^b(R^H))$.

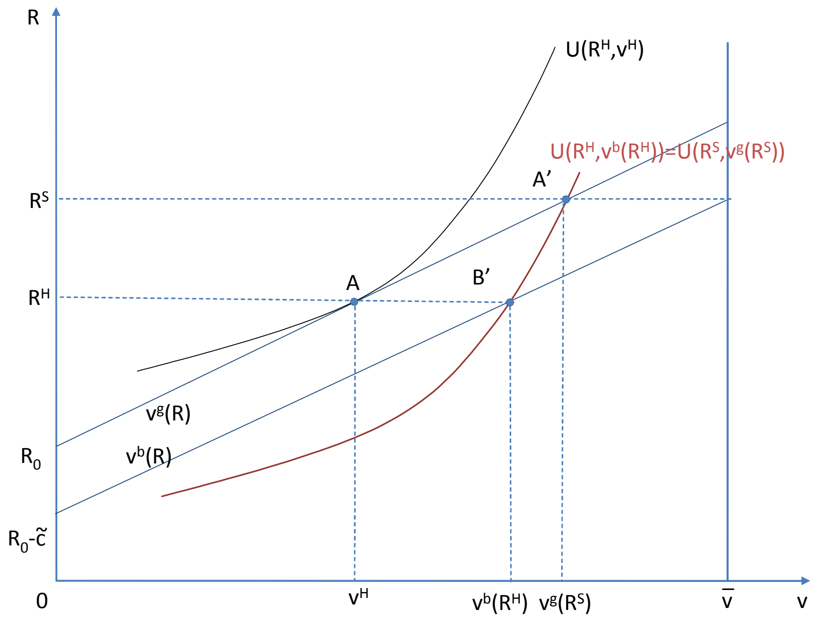

Figure 2: The special operating cost $\tilde{c}$

Taking R^H as given and using Eq. (2), we can show that the utility of the manipulating bad bank is decreasing in c:

$$\frac{dU(R^H, v^b(R^H, c))}{dc} = \frac{\partial U(R^H, v^b(R^H, c))}{\partial v^b(R^H, c)} \frac{dv^b(R^H, c)}{dc} = \theta^{-1} U_v < 0. \tag{5}$$

On the other hand, using Eq (3) to determine $dR^S/dc = -1$ and Eq. (2), to get $dv^g(R^S)/dR^S = \theta^{-1}$ we can show that the utility of the good bank that implements the signaling strategy is increasing in c :

$$\begin{aligned} \frac{dU(R^S(c), v^g(R^S(c)))}{dc} &= \frac{\partial U()}{\partial R^S}\left(\frac{dR^S}{dc}\right) + \frac{\partial U()}{\partial v^g}\frac{dv^g(R^S(c))}{dR^S(c)}\left(\frac{dR^S}{dc}\right) = \\ &= -U_R - U_v\theta^{-1} = -\theta^{-1}U_R[\theta - MRS(R^S, v(R^S))]. \end{aligned} \tag{6}$$

But outside the optimum of the good bank, for $R^S > R^H$, the marginal rate of substitution $MRS = -U_v/U_R > \theta$, thus the derivative has a positive sign.

Thus, for any $c < \tilde{c}$ we have $U(R^S, v^g(R^S)) < U(R^H, v^b(R^H))$ and for $c > \tilde{c}$, $U(R^S, v^g(R^S(c))) > U(R^H, v^b(R^H, c))$. This is the case depicted in Figure 1.

3 Equilibria

An equilibrium of this game is defined as a situation where banks' strategies are optimal (allow their CEO to earn the highest compensation) given shareholders' beliefs about the type of bank, and shareholders' beliefs are correct given banks' optimal strategies. We may distinguish between a separating equilibrium (where the strategy of the banks perfectly reveals their type), a pooling equilibrium (where all banks implement the same strategy and thus no information about the type of bank can be inferred from the observed earning strategy), and a hybrid equilibrium (wherein banks play Nash mixed strategies and their strategy carry some information about their type).

In order to rule out a trivial situation, we admit that, by increasing risk enough, bad banks can deliver the perfect information optimal return of the good bank, or, in an equivalent way, that $R^S > R^H$.[8] If bad banks cannot copy the strategy of the good banks, only the latter do survive and implement the perfect information strategy R^H.

[8] In turn, this condition is met only if the operating cost is not too big, i.e. if $c < R_0 + \theta\bar{v} - R^H$.

3.1 Signaling equilibrium: good banks do R^S

We can show that an elementary separating equilibrium where all good banks deliver their signaling return R^S and bad banks have left the market is always possible.

In such an equilibrium, good banks' strategy is $s(g) = R^S$. The equilibrium beliefs are: $\Pr[g|R^S] = 1$, and, given that any bank that pays less than R^S should be a bad bank, $\Pr[g|R^L] = 0$ and $\Pr[g|R^H] = 0$.

Bad banks can play either R^L or R^H, but given the system of beliefs, the manager's payoff is: $W\left(R^L\right) = W\left(R^H\right) = 0$. There is no incentive for a bad bank to stay in the market. Furthermore, R^S is the optimal strategy for the good bank: indeed, the condition $W\left(R^S\right) > W\left(R^H\right) = 0$ is always true.

In this equilibrium, the risk exposure of good banks exceeds the perfect information level, $v^g(R^S) > v^g(R^H)$. Good banks resort to excessive risk taking as a barrier to entry.

3.2 Pooling equilibrium: all banks do R^H

We can now put forward the existence of a pooling equilibrium where all banks play R^H : bad banks play the perfect information optimal strategy of good banks, and good banks decide not to signal themselves by doing R^S. Banks' single strategy is $s(i) = R^H$, $\forall i \in \{b, g\}$.

Shareholders' equilibrium beliefs can be written: $\Pr[g|R^S] = 1$, $\Pr[g|R^H] = q$ and $\Pr[g|R^L] = 0$.

Necessary conditions for this equilibrium are: (1) $W(R^H) > W(R^S)$ for the good bank and (2) $W(R^H) > W(R^L) = 0$ for the bad bank. Since $W(R^S) > 0$, the equilibrium exists under the single condition $W(R^H) > W(R^S)$. Given the definition of the manager's payoff (Eq. 4), this condition becomes:

$$qU(R^H, v^g(R^H)) + (1-q)\, U(R^H, v^b(R^H)) > U(R^S, v^g(R^S)) \tag{7}$$

or:

$$q > q_1 \equiv \frac{U(R^S, v^g(R^S)) - U(R^H, v^b(R^H))}{U(R^H, v^g(R^H)) - U(R^H, v^b(R^H))}. \tag{8}$$

In the small operating cost case ($c < \tilde{c}$), we have $U(R^S, v^g(R^S)) < U(R^H, v^b(R^H))$ that implies $q_1 < 0$: the previous condition is always true. The pooling equilibrium always exists if the loss of utility of shareholders who support a bad bank is not too large; this can happen if the operating cost gap c is small.

In the large operating cost case ($c > \tilde{c}$), we have $U(R^S, v^g(R^S)) > U(R^H, v^b(R^H))$, thus $q_1 > 0$. Furthermore, $q_1 < 1$ as $U(R^S, v^g(R^S)) < U(R^H, v^g(R^H))$. We can conclude that in the large cost case, the pooling equilibrium exists only if the frequency of good banks is large enough. If there are not too many bad banks who imitate the good banks, the manager of the latter has not too much to lose, and it does not worth for him to implement an expensive signaling strategy.

In the pooling equilibrium, bad banks take too much risks as compared to the perfect information set-up, but they all survive in this environment.

3.3 Hybrid equilibrium: some good banks signal themselves, all others play R^H

In this equilibrium, a proportion α of the good banks decide to signal themselves by playing R^S, and $(1-\alpha)$ play their perfect information strategy R^H. All bad banks copy the latter and play R^H.

The mixed equilibrium strategy of the good banks is $s(g) = \{\alpha R^S + (1-\alpha)R^H \ |\alpha \in [0,1]\}$ and the bad banks' strategy is $s(b) = R^H$. Using Bayes rule, and denoting by $\Pr[R^j|i]$ the probability that a bank of type i plays strategy R^j, equilibrium beliefs can be written: $\Pr[g|R^L] = 0$, $\Pr[g|R^S] = 1$ and:

$$\Pr[g|R^H] = \frac{\Pr[R^H|g]\Pr[g]}{\Pr[R^H]} = \frac{(1-\alpha)q}{(1-\alpha)q + (1-q)}. \quad (9)$$

In equilibrium, a good bank must be indifferent between strategies R^H and R^S:

$$W(R^S) = W(R^H) \Leftrightarrow U(R^S, v^g(R^S)) = \Pr[g|R^H]U\left(R^H, v^g(R^H)\right) + \Pr[b|R^H]U\left(R^H, v^b(R^H)\right). \quad (10)$$

This equation allows us to determine $(1-\alpha)$ with respect to predetermined variables:

$$(1-\alpha) = \frac{(1-q)}{q}\frac{\left[U(R^S, v^g(R^S)) - U\left(R^H, v^b(R^H)\right)\right]}{\left[U\left(R^H, v^g(R^H)\right) - U(R^S, v^g(R^S))\right]}. \quad (11)$$

We first notice that $U\left(R^H, v^g(R^H)\right) - U(R^S, v^g(R^S)) > 0$. Hence, in the small cost case ($c < \tilde{c}$), since $U(R^S, v^g(R^S)) < U\left(R^H, v^b(R^H)\right)$ we have $(1-\alpha) < 0$: the hybrid equilibrium is impossible.

In the large cost case ($c > \tilde{c}$), we have $U(R^S, v^g(R^S)) > U(R^H, v^b(R^H))$, so $1 - \alpha > 0$. The equilibrium exists if $1 - \alpha < 1$, which is equivalent to:

$$q > q_1 \equiv \frac{U(R^S, v^g(R^S)) - U\left(R^H, v^b(R^H)\right)}{U\left(R^H, v^g(R^H)\right) - U\left(R^H, v^b(R^H)\right)}. \tag{12}$$

This is the same existence condition as that of the pooling equilibrium in the same large cost case (Eq 8).

In the hybrid equilibrium, both bad banks and a fraction α of the good banks are taking an excessive risk. The maximum amount of risk in the economy appears for $\alpha \to 1$; we infer that if the hybrid equilibrium is in place, the amount of risk in this economy reaches its highest level for $c \searrow \tilde{c}$.

Table 1 presents a summary of the possible equilibria. Except for the case of large costs and a high proportion of bad banks ($q < q_1$), the game features a typical configuration of multiple equilibria, where the equilibrium that will actually materialize depends on investors' beliefs. In any equilibrium, banks take too much risks compared to the perfect information case.

	Small cost ($c < \tilde{c}$)	Large cost ($c > \tilde{c}$)
$q < q_1$	separating, pooling	separating
$q > q_1$	separating, pooling	separating, pooling, hybrid

Table 1. Summary of possible equilibria

4 Conclusion

There is widespread consensus that the origin of the 2007-2009 financial crisis was an abnormal accumulation of risk by banks throughout the world. The analysis in this paper connects this race for risk to imperfect information in the banking sector. In a world where returns can be observed but risk cannot, banks running with high operating costs would take more risk only to deliver higher returns and be perceived as highly efficient banks. The latter can signal themselves by further increasing risks well above their optimal, perfect information level.

The game presents several equilibria, all being characterized by excessive accumulation of risk by banks compared to the ideal, perfect information case. The policy implications are straightforward. Any reform able to reduce the asymmetry of information between banks' managers and outsiders should eliminate the key reason for the risk race. Yet there should be no miracle solution able to achieve this result. If banks' exposure to risk is hard to assess by outsiders and at least some good banks implement their high-risk signaling strategy, then stronger regulation is needed to cap the maximum amount of risk banks can take. In the light of this model, the decision of the G20 leaders in September 2009 to impose on banks tighter capital requirements and a new leverage limit should go in the right direction.

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