Does collateral fuel moral hazard in banking?

J-P. Niinimäki
Helsinki School of Economics and HECER

Discussion Paper No. 181
August 2007

ISSN 1795-0562
Does collateral fuel moral hazard in banking?

Abstract

This paper explores how loan collateral affects the problem of moral hazard between banks and a deposit insurance agent. First, when the collateral value is certain, it attenuates the volatility of bank returns, thereby making banks more safe and mitigating moral hazard. Here, the paper presents three simple models, in which the collateral value fluctuates and fuels moral hazard. The latter findings are broadly consistent with the characteristics of the topical subprime mortgage crisis.

JEL Classification: G21, G22, G28

Keywords: Collateral, Subprime Lending, Subprime Mortgage Crisis, Deposit Insurance, Moral Hazard

J-P. Niinimäki

Department of Economics
Helsinki School of Economics
P.O. Box 1210
FI-00101 Helsinki
FINLAND

e-mail: juha-pekar.niinimaki@hse.fi
1. Introduction

In the U.S.A numerous subprime banks are presently failing. Subprime banking represents a novel and rapidly growing segment of the mortgage market that channels loans to those borrowers, who fail to meet credit quality requirements in the standard mortgage market. This paper poses the question of whether banks, for example subprime banks, gamble with the value of collateral (real estate). Borrowers of the subprime banks are risky clients but their loans are secured by house property. Even when a borrower cannot earn sufficient income to repay the loan, the bank does not face a loan loss if the value of house property appreciates during the loan period. Thus, the bank makes handsome profits if the collateral value appreciates. If the value of the real estate depreciates, the bank fails because a large share of the borrowers is unable to repay their loans and the value of the collateral does not cover loan repayments. Consequently, the banks are de facto gambling with the upcoming value of real estate.¹

According to the classic banking theory, collateral reduces bank risk. Even when a borrower has insufficient income to repay his loan, a bank can seize the collateral (Bester, 1985; 1987). This traditional argument has been brought fore in several articles. For brevity, we mention only one example:

"The value of a bank’s assets is most likely to fall if borrowers default on their loans or changes in asset prices generate falls in the value of their marketable investments. In both cases, banks can reduce the risks they face by appropriate pricing and screening of transactions, diversifying their asset portfolio or taking collateral (Bell & Pain, 2000, p.113)."

This paper does not deny that collateral reduces bank risk. Rather, the accuracy of the argument is investigated and confirmed in Section 4. Since the value of collateral is certain, it attenuates the volatility of bank income and thereby creates two positive impacts. First, collateral may prevent bank failures and make banks risk-free. Second, it may eliminate the moral hazard problem. That is, the bank will not take excessive risks in lending.

¹ For subprime lending see Chomsisengphet & Pennington-Cross (2006). Chomsisengphet & Pennington-Cross find that the subprime premium, the difference between the prime and subprime rates, charged to a subprime borrower is around 2 percentage points. This makes subprime loans attractive to banks. However, evidence indicates that on average the probability of default is at least six times higher for nonprime loans than for prime loans.
The positive effects of collateral are challenged in Sections 4-6. The sections put forward three models, in which the introduction of collateral generates the moral hazard problem. In each model, the collateral value fluctuates. In Section 4, bank returns are certain without collateral and the moral hazard problem is avoided. Thereafter, collateral is introduced. Its upcoming value is uncertain, which tempts banks to gamble with the collateral. Banks refrain from costly efforts in borrower evaluation, but lending decisions are based on the collateral. If the collateral value is high at the later date, the bank makes a profit. If the collateral value depreciates, the bank fails and the bank regulator, who runs the deposit insurance scheme, pays the costs of excessive risk taking. Section 5 extends the analysis by demonstrating that the negative effects of collateral are severe if the upcoming value of collateral is closely correlated with the upcoming probability of project success. Section 6 models the example of a subprime bank. The moral hazard effect is shown to be strengthen when outside collateral is replaced with inside collateral, which is funded with the loan capital.

The paper is related to recent research on moral hazard in banking: e.g. Matutes & Vives (1996, 2000), Blum (1999, 2002), Chiesa (2001), Niinimäki (2001), Repullo (2004), Decamps & Rochet & Roger (2004), Jeitschko & Jeung (2005) and Kopecky & VanHoose (2006). When Bester (1985, 1987) investigates how collateral affects the risk of a single loan, the question to be answered is: how does collateral influence on bank risk at the aggregate level. Does collateral alleviate or worsen the bank’s risk of failure? We are primary interested in investigating the scenarios, if any, in which collateral can fuel moral hazard in banking. As mentioned above, we are able to observe these scenarios. Our findings are rather consistent with existing empirical evidence which is surveyed in Section 2. Put differently, the purpose of this paper is to design simple models on loan markets that are based on a few stylized facts given in Section 2 and that can reproduce a few results consistent with the evidence of Section 2. Based on empirical evidence, it is known that banking crises are closely linked to fluctuations in the value of real estate. The paper proposes a theory which explains why banking crisis are connected with fluctuations in real estate markets.

Section 2 reviews empirical evidence and Section 3 presents the model framework. Section 4 examines how collateral mitigates moral hazard. Sections 5, 6 and 7 present three examples in which collateral may fuel moral hazard, and Section 8 concludes.
2. Empirical evidence

This section surveys the empirical evidence on collateral, fluctuations in real estate markets and the relationship between collateral value and banking crises.

*Observation 1. The ratio of collateral to loan size is high.* According to Binks et al. (1993) and de Meza & Southey (1996), in the U.S.A the ratio of collateral to loan is, on average, 1:2 and in the Great Britain exceeds unity for 85% of loans. In the study by Gonas & Highfield & Mullineux (2004), 73% of loans for US firms are secured.

*Observation 2. A major portion of collateral consists of real estate.* According to Borio’s (1996) observations, the portion of loans secured by real estate collateral varies in different countries: 59% in Great Britain, 56% in Canada and 66% in United States.

*Observation 3. Collateral value, most of all the value of real estate, fluctuates substantially.* In Stockholm, for example, inflation-adjusted property prices rose rapidly in the late 1980s, rising to 450% of the level at the beginning of the decade. From 1989 to 1993, inflation-adjusted property prices depreciated to less than the 1982 level (Herring & Wachter, 1999). US farmland prices appreciated sharply from 1972, peaking in 1981 to more than twice the 1972 level. From 1981 to 1998, prices reverted to the original level (Herring & Wachter, 1999). In Japan, commercial property prices rose over 300% during the 1980s despite a very modest inflation rate in consumer prices, but declined again to the initial level over the next five years (Hilbers & Lei & Zacho, 2001). Using non-performing commercial real estate loans held by FDIC receiverships, Freund & Seelig (1993) investigate changes in the value of collateral on loan-by-loan basis. Average depreciation in collateral value was 54%. In three-quarters of the loans, the 1992 collateral value was at least 25% below the original evaluation.

*Observation 4. Banking crises are commonly preceded by a depreciation in the value of real estate.* Herring and Wachter (1999, p. 2), for instance, document the following:

“One striking feature of the current Asian financial crisis is that the most seriously affected countries first experienced a collapse in property prices and a consequent weakening of their banking systems before an exchange rate crisis.”

In their empirical research, Hilberts & Lei & Zacho (2001) find that on average, real estate prices, adjusted for inflation rose more than 20% within 2 to 7 years before the onset of financial distress but fell more than 15% during the two years prior to the beginning of financial distress. After the onset of financial crises, real estate prices often continued to fall. Zhu’s (2003) empirical study
focuses on the level of banking profitability and loan loss provisions during the upswing and downward phases of real estate markets. On average, bank profits are almost halved, and loan loss provisions nearly doubled when the value of real estate depreciates. In the FDIC’s extensive empirical analysis on the Savings and Loan Crisis, Hanc (1998, p. 19-24) offers the following conclusions regarding four major regional and sectoral recessions that were associated with widespread bank failures: “Commercial and real estate markets in particular deserve attention because boom and bust activity in these markets was one of the main causes of losses at both failed and surviving banks.” For more evidence, see Allen & Madura & Wiant (1995).

Observation 5. Collateral value is correlated with the cycles of the economy. In their cross-country empirical analysis based on a sample of 17 developed economies, Davis & Zhu (2004) find that GDP has an important impact on commercial property prices. Their findings are supported by Abraham & Hendershott (1996), who discover that real income growth has a positive effect on real house prices. According to Jacobsen & Naug (2005), household income raises house prices, while unemployment reduces them in Norway. For more evidence, see Lamont & Stein (1999).
3. Economy

The paper includes four models for investigating how collateral affects bank risk. Although the models are separate, they have a few common characteristics, which are presented now.

Consider a risk-neutral economy with banks, borrowers (= entrepreneurs) and a bank regulator. Each entrepreneur can undertake an investment project, which requires a unit of input capital. Since the entrepreneur has no capital of his own, he needs to seek financing from a bank. Bank size is 1 and it has no capital of its own. The bank funds its lending by attracting deposits at the interest rate of the economy, $r$. The deposits are insured by the bank regulator. As is common in this type of model, it is assumed that the regulator cannot directly observe the project risks and loan interest rates. However, the regulator can impose a ruling that banks to grant only collateralized loans.

An entrepreneur can choose from two project types: a good project or a bad project. When successful, the good project produces $Y_g$ units. Its expected probability of success is $\mu_g$ and its NPV (net present value) is assumed to be clearly positive,

$$\mu_g Y_g > r + m.$$  

(3.1)

The expected project output covers the interest payment and the cost of monitoring, $m$. When successful, the bad project produces $Y_b$ units. Its expected probability of success is $\mu_b$ and its NPV is assumed to be negative,

$$\mu_b Y_b < r.$$  

(3.2)

If unsuccessful, both project types yield no output. As is usual in risk-shifting models, the bad project is assumed to be risky in comparison with the good project. Its expected probability of success is low, $\mu_b < \mu_g$, but when it succeeds, the output is large, $Y_b > Y_g$.

---

2 We assume that a bank manager who monitors the borrowers also owns the bank. Jeitschko & Jeung (2005) investigate risk taking in the case that the bank is owned by shareholders, but the bank manager makes the loan decisions. They observe three optimal risk levels: the manager’s most-preferred asset risk, the shareholders’ most-preferred asset risk and the optimal risk choice of the deposit insurer.
Suppose that a bank grants a loan to the entrepreneur at the interest rate of the
economy, \( r \). In the absence of monitoring, the risk-shifting problem is assumed to surface. The
entrepreneur chooses the bad project since it is expected to yield higher profits to him

\[
\mu_c (Y_c - r) < \mu_b (Y_b - r).
\]

The risk-shifting problem can be eliminated by monitoring the entrepreneur. The task is delegated
to the bank, which monitors borrowers on the behalf of depositors. Unfortunately, since monitoring
incurs a non-monetary cost, \( m \), to the banker, there is a temptation to neglect it. This generates the
problem of moral hazard between the bank and the bank regulator. When the bank neglects
monitoring, it may earn handsome returns because it has forgone the costs of monitoring.
Alternatively, the bank fails. The banker does not lose anything since the bank regulator, who is a
deposit insurance agent, repays the depositors. The banker will exert efforts to monitoring only if it
is at least as profitable to the bank as neglecting monitoring.

For brevity, several assumptions are made when the problem of moral hazard is
constructed. For example, the model is mainly constructed so that a monitoring bank is risk-free.\(^3\)
Thus, under monitoring the deposit insurance premium is zero.\(^4\) In addition, with monitoring the
bank makes zero profits because of perfect competition. This makes it easy to examine moral
hazard. The bank neglects monitoring if the non-monitoring strategy yields any profits for it.

\(^3\) In Section 4, a monitoring bank is risk-free if the loans are secured with collateral.

\(^4\) The deposits are insured, for example, in order to eliminate bank runs (Diamond & Dybvig, 1983; Niinimäki, 2003).
4. Uncertain loan losses, certain collateral

In this section the value of collateral is certain, whereas the upcoming share of successful loans is uncertain. The analysis shows that in this environment the introduction of collateral is beneficial since it mitigates moral hazard and may make banking risk-free with monitoring.

To begin with, the model framework needs to be detailed. The upcoming share of successful loans (vice versa loan losses) depends on the upcoming state of the economy (e.g. boom or recession), which is unknown at the beginning of period, when banks grant loans and entrepreneurs invest the loan capital in their projects. With probability \( b \), the economy later booms and with probability \( 1 - b \) a recession takes place.

Suppose, first, that a bank monitors. If the economy booms, a project (and a loan) succeeds with probability \( \bar{n}_o \). With a recession, the project succeeds with probability \( n_o \), \( n_o < \bar{n}_o \). The expected probability to succeed is

\[
\mu_o = b \bar{n}_o + (1 - b)n_o .
\]  

(4.1)

As regards to the bank’s loan portfolio, the upcoming share of successful loans is \( \bar{n}_o \) within a boom period and \( n_o \) in a recession, whereas the expected share of successful loans is \( \mu_o \).

In the absence of monitoring, a project succeeds with probability \( \bar{n}_b \) under a boom and with probability \( n_b \) in a recession, \( n_b < \bar{n}_b \). It is assumed that

\[
n_b \leq n_o , \quad \bar{n}_b \leq \bar{n}_o .
\]  

(4.2)

In the loan portfolio, the share of successful loans is \( \bar{n}_b \) during a boom and \( n_b \) in a recession, whereas the expected share of successful projects is

\[
\mu_b = b \bar{n}_b + (1 - b)n_b .
\]  

(4.3)

It is assumed that a defaulted loan cannot be more valuable to the bank than a performing loan:
**Assumption 1.** The bank’s income from collateral is, at a maximum, equivalent to the loan repayment.

We will first investigate bank returns under monitoring and thereafter in the absence of monitoring.

### 4.1 Under monitoring

Several alternative collateral–interest rate combinations exist which yield the same profits to a borrower. Suppose that the borrower has a fixed amount, \( C \) units, outside collateral. A break-even loan interest rate, \( R \), can be solved from

\[
\mu R + (1-\mu)C = r + m. \tag{4.4}
\]

The expected loan repayments to the bank, \( \mu R \), and expected collateral proceeds from unsuccessful projects, \( (1-\mu)C \) together cover the costs of banking: interest payments on deposits and the non-monetary costs of monitoring, \( r + m \). The break-even loan interest rate is

\[
R(C) = \frac{m + r - (1-\mu)C}{\mu}, \tag{4.5}
\]

and it is declining in collateral; the borrower is ready to pledge collateral only if this alternative offers him a reduction in the interest rate. If \( C = m + r \), we see that \( R = C \) and the loan is fully collateralized. The borrower’s expected profits from the good project are \( \mu(Y - R) - (1-\mu)C \).

When the project succeeds, the borrower obtains the output and can repay the loan. When the project fails, the borrower loses the collateral. Given (4.5), the expected profits from the good project are

\[
\pi = \mu Y - r - m > 0. \tag{4.6}
\]

Only now, when the loan interest rate is defined, the following assumption can be made.

**Assumption 2.** \( n R(0) < r \).
Assumption 2 details the benefits from collateral. A monitoring bank fails when the upcoming share of successful loans is small if the loans are not secured with collateral.

As for the bank returns, two cases arise, depending on whether the upcoming share of successful loans is large or small. When it is large, \( \bar{n}_o \), the bank earns \( \bar{n}_o R_o(C) + (1 - \bar{n}_o)C - r \). Inserting the loan interest rate from (4.5) into this equation gives the restated bank returns

\[
\frac{\bar{n}_o (m + r) - \mu_o r - (\bar{n}_o - \mu_o)C}{\mu_o} .
\]

Since \( \bar{n}_o > \mu_o \) bank returns are decreasing in collateral and they are at least \( m \).

When the realized share of successful loans is small, \( \underline{n}_o \), the bank returns are

\[
\frac{n_o (m + r) - \mu_o r + (\mu_o - n_o)C}{\mu_o} .
\]

Recall that the bank fails without collateral, \( n_o (m + r) < \mu_o r \) (Assumption 2). Now, according to (4.8), collateral increases bank returns since \( \mu_o > n_o \). If \( C \) is sufficiently large, the bank does not fail even when the realized share of successful loans is small. This is easy to verify by inserting \( C = r + m \) into (4.8). Collateral makes the bank risk-free by increasing its returns during a recession, since even the unsuccessful loans yield some income (collateral) to the bank.

Intuitively, collateral attenuates the volatility of bank returns in two ways. First, it cuts the loan interest rate, thus decreasing bank returns from successful loans. Second, it increases the returns from unsuccessful loans. Due to the introduction of collateral, bank returns decrease during an economic boom when the share of successful loans is large (recall (4.7)). In contrast, bank returns increase during a recession when the share of successful loans is small (see (4.8)).

4.2 In the absence of monitoring

Suppose that the bank suggests the non-monitoring strategy to the borrower. Instead of monitoring and forcing the borrower to select the good project, the bank agrees to neglect monitoring so that
the borrower can choose the bad project. The borrower accepts the offer if his expected profits from
the bad project are at least equal to those from the good project

\[ \mu_b(Y_b - R_b(C)) - (1 - \mu_b)C \geq \pi_G. \] (4.9)

From which it is easy to solve the highest loan interest rate that is acceptable to the borrower

\[ R_b(C) = \frac{\mu_b Y_b - (1 - \mu_b)C - \pi_G}{\mu_b}. \] (4.10)

Only now, when the loan interest rate is defined, the following assumption can be made

**Assumption 3.** \( \bar{n}_b R_b(0) > r. \)

Assumption 3 is not essential, but it highlights the benefits from collateral. A non-monitoring bank can repay the depositors in an economic boom, that is, when a large share of loans is successful.

Expected bank returns are now explored. Suppose first that the upcoming share of successful loans is large so that the bank earns returns \( \bar{n}_b R_b + (1 - \bar{n}_b)C - r. \) Given the loan interest rate (4.10), the bank returns can be restated

\[ \bar{n}_b (\mu_b Y_b - r) - \bar{n}_b \pi_G - (\bar{n}_b - \mu_b) (C - r) \]

\[ \mu_b \] (4.11)

Without collateral, the bank returns are positive (Assumption 3). The problem of moral hazard may appear: the bank optimally neglects monitoring. It is, however, easy to see from (4.11) that the returns from the non-monitoring strategy are decreasing in collateral. If the amount of collateral is large, for example \( C = R_b, \) the bank returns, \( \bar{n}_b R_b + (1 - \bar{n}_b)C - r, \) simplify to \( R_b - r. \) Yet, from (4.10) it is possible to see that \( R_b < r \) when \( C = R_b \) and thus the bank fails. Suppose now that the upcoming share of successful loans is small. When \( C = R_b, \) the bank returns, \( \bar{n}_b R_b + (1 - \bar{n}_b)C - r, \) again simplify to \( R_b - r, \) and the bank fails, since \( R_b < r \) when \( C = R_b \) (see (4.10)). Hence, when the amount of collateral is sufficiently large the non-monitoring strategy is unprofitable whatever the share of successful loans, and thus the bank optimally monitors.
The intuition is the same as in Section 4.1. Collateral attenuates the volatility of bank returns by cutting the loan interest rate and thereby decreasing bank returns when the share of successful loans is large. The attenuation of volatility leads to the elimination of moral hazard since gambling is on average unprofitable, \( \mu_b Y_b < r \). Gambling is profitable only if the volatility of bank returns is sufficiently large. Put differently, when the collateral requirement is sufficiently large, entrepreneurs are willing to borrow only if the loan interest rate is lower than the deposit interest rate. This makes banking unprofitable.

Suppose that the bank sets such a collateral requirement that makes it risk-free under monitoring (Section 4.1). Does this amount of collateral eliminate moral hazard? It is easy to give a counter example. Consider the following economy:

\[
\begin{align*}
\tilde{n}_o &= 0.9, \quad n_{o} = 0.8, \quad \bar{n}_o = 0.9, \\
\tilde{\pi}_o &= 0.8, \quad \pi_{o} = 0.042. 
\end{align*}
\]

Using (4.8), it is possible to verify that when \( C = 0.42 \), a monitoring bank is risk-free. Suppose that the bank regulator imposes collateral requirement \( C = 0.42 \). Under monitoring, the bank is now risk-free, but it earns zero profits. It is easy to see from (4.11) that by neglecting monitoring the bank enjoys positive returns. Thus, when \( C = 0.42 \), the bank optimally neglects monitoring. Now (4.11) reveals that if the bank regulator implies collateral requirement \( C = 0.75 \) the non-monitoring strategy is unprofitable. The bank optimally monitors and is risk-free.

**Proposition 1.** When the upcoming share of successful loans is uncertain, but the value of collateral is certain, collateral attenuates the volatility of bank returns and thereby creates two positive effects. First, it increases expected returns from monitoring during a recession, thus preventing a bank failure. Second, it decreases the returns from the non-monitoring strategy during a boom, making the non-monitoring strategy unprofitable.

Consequently, the bank regulator should require banks to grant loans only against collateral.\(^5\)

\(^5\) Alternative methods exist for mitigating moral hazard in banking: e.g. ceilings on interest rates (Matutes & Vives, 2000; Repullo, 2004), risk-based deposit insurance premiums (Matutes & Vives, 2000), subordinated bank debt (Blum, 2002; Decamps & Rochet & Roger, 2004), franchise value (Chiesa, 2001; Repullo, 2004) and bank equity capital (Rochet, 1992; Blum, 1999; Chiesa, 2001; Niinimäki, 2001; Repullo, 2004; Kopecky & VanHoose, 2004, 2006; Decamps & Rochet & Roger, 2004; Jeitschko & Jeung, 2005).
5. Certain loan losses, uncertain collateral

In this section the upcoming share of successful loans is certain, but the upcoming value of collateral fluctuates. The section examines how the introduction of collateral may generate the moral hazard problem when banks can gamble with the fluctuating value of collateral.

To begin with, the model setting is updated. Under monitoring, a loan succeeds with certain probability $\mu_\alpha$ while in the absence of monitoring it succeeds with certain probability $\mu_\beta$. In the bank’s loan portfolio, the share of successful loans is equal to its expected value: $\mu_\beta$ in the absence of monitoring and $\mu_\alpha$ under monitoring. The upcoming value of collateral is uncertain. To keep the analysis simple, the collateral value is modelled in an elementary way. With probability $h$ it is high, $\alpha C$, and with probability $1-h$ it is low, $\alpha C$, $0 \leq \alpha < 1 < \overline{\alpha}$. The current value of collateral is equal to its expected value

$$C = [h\overline{\alpha} + (1-h)\alpha] C.$$  \hspace{1cm} (5.1)

For brevity, the following assumption is made

**Assumption 4.** $m - (1 - \mu_\alpha) C (1 - \alpha) > 0$.

Assumption 4 implies that under monitoring, bank returns can cover payments on deposits and the bank is risk-free. The moral hazard problem is assumed to appear without monitoring in both cases $\overline{\alpha} C > r$ and $\overline{\alpha} C < r$. That is, without monitoring, a borrower chooses the bad project

$$\mu_\alpha (Y_\alpha - r) + (1-\mu_\alpha) h \text{Max}[0, \overline{\alpha} C - r] \ < \ \mu_\beta (Y_\beta - r) + (1-\mu_\beta) h \text{Max}[0, \overline{\alpha} C - r] .$$ \hspace{1cm} (5.2)

Since the collateral value can appreciate, it may exceed $r$ and the borrower has wealth, $\overline{\alpha} C - r$, even when his project fails.
5.1 Under monitoring

Note that without collateral, the borrower’s expected returns are $\pi_g = \mu_g Y_g - r - m > 0$. He accepts such loan interest rate / collateral combinations, which satisfy his participation constraint

$$\mu_g (Y_g - R_g) - (1 - \mu_g)C = \pi_g,$$

from which it is easy to solve the loan interest rate

$$R_g(C) = \frac{r + m - (1 - \mu_g)C}{\mu_g}.$$ (5.3)

Since a certain share of loans succeeds, the bank returns are $\mu_g R_g + (1 - \mu_g)\bar{\alpha}C - r > 0$, when the upcoming value of collateral is high and $\mu_g R_g + (1 - \mu_g)\alpha C - r > 0$, when it is low. Thanks to Assumption 4, the bank can pay back deposits in both cases. More importantly, the bank is now risk-free without collateral since $\mu_g R_g(0) - r = m > 0$.

5.2 In the absence of monitoring

The bank neglects monitoring and borrowers can invest in the bad projects. The loan interest rate / collateral combinations need to satisfy the borrower’s participation constraint

$$\mu_b (Y_b - R_b) - (1 - \mu_b)C + (1 - \mu_b)\bar{\alpha}h \text{Max}( 0, \bar{\alpha}C - R_b ) = \pi_g.$$ (5.4)

Two cases occur, depending on whether $\bar{\alpha}C < R_b$ or $\bar{\alpha}C > R_b$.

5.2.1 The case $\bar{\alpha}C < R_b$

In this section it is assumed that $\bar{\alpha}C < R_b$ (more precisely, $\bar{\alpha} < \left[ \mu_b Y_b - \pi_g - (1 - \mu_b)C \right]/\mu_b C$). The loan interest rate can be solved from (5.4) as
Without collateral, bank returns are certain and negative \( \mu_y R_y(0) - r = \mu_y Y_y - \pi_y - r < 0 \), given (3.2). The non-monitoring strategy is unprofitable, the moral hazard problem is avoided and the bank optimally monitors! With collateral, the expected bank returns are

\[
R_y(C) = \frac{\mu_y Y_y - \pi_y - (1 - \mu_y)C}{\mu_y}.
\] (5.5)

Inserting loan interest rate from (5.5) into (5.6) gives

\[
h \text{Max} \left[ \mu_y R_y + (1 - \mu_y)\overline{\alpha}C - r, 0 \right] + (1 - h) \text{Max} \left[ \mu_y R_y + (1 - \mu_y)\alpha C - r, 0 \right].
\] (5.6)

In the second set of brackets (the collateral value is low) the first term is negative since \( \mu_y Y_y < r \).

In the first set of brackets (the collateral value is high) the first term is positive if \( (1 - \mu_y)(\overline{\alpha} - 1)C \) is sufficiently large. This is true if the initial amount of collateral, \( C \), is relatively high and if the collateral value appreciates; that is, \( \overline{\alpha} \) is great. Then, the bank earns profit

\[
\mu_y Y_y - r - \pi_y + (1 - \mu_y)(\overline{\alpha} - 1)C,
\] (5.8)

which is, of course, increasing in \( C \) and \( \overline{\alpha} \). Since the variance of the collateral is increasing in \( \overline{\alpha} \) (Appendix A), the expected bank returns are high when the collateral value fluctuates widely. Yet, the constraint \( \overline{\alpha}C < R_y(C) \) also needs be satisfied. It can be written as

\[
\overline{\alpha} < 1 + \frac{\mu_y Y_y - \pi_y - C}{\mu_y C}.
\] (5.9)
Since we must have $\bar{\alpha} > 1$, this determines restrictions also on $C$. This problem is discussed in Remark 1 below. Footnote 5 gives a numeric example, which satisfies the constraints.\footnote{Suppose that $\mu_G = 1$, $Y_G = 1.05$, $r = 1.03$, $m = 0.01$, $Y_b = 1.25$, $\mu_b = 0.8$, $h = \frac{1}{2}$, $\bar{\alpha} = 1.3$, $\alpha = 0.7$, $C = 0.7$. Under these values, $R_G = 1.04$, $R_b = 1.0625$. When the collateral value appreciates, it is less than the loan repayment since $0.7 \times 1.3 = 0.91 < 1.0625$. As a result, the bank receives the whole collateral, 0.91, when the project is unsuccessful. Since 80\% of bank loans succeed, it earns profits, $0.8 \times 1.0625 + 0.2 \times 0.91 - 1.03 = 0.002$. Hence, the bank optimally neglects monitoring.}

**Proposition 2.** When the upcoming share of successful loans is certain, but the upcoming value of collateral is uncertain, the introduction of collateral may generate the moral hazard problem. The larger the volatility of the upcoming value of collateral, the worse the moral hazard problem.

Moral hazard appears when the initial value of collateral, $C$, is relatively high. A banking crisis occurs when the collateral value depreciates. This is consistent with Observation 4 in Section 2.

### 5.2.2 The case $\bar{\alpha}C > R_b$

Now $\bar{\alpha}C > R_b$ or more precisely $\bar{\alpha} > \frac{\mu_bY_b - \pi_G - (1 - \mu_b)C}{\mu_b + (1 - \mu_b)h}$. The loan interest rate can again be solved from (5.4)

$$R_b(C) = \frac{\mu_bY_b - \pi_G - (1 - \mu_b)(1 - h)\bar{\alpha}C}{\mu_b + (1 - \mu_b)h}. \quad (5.10)$$

The constraint $\bar{\alpha}C > R_b$ means that

$$\frac{\bar{\alpha}}{\alpha} > 1 + \frac{\mu_bY_b - \pi_G - C + (1 - \mu_b)hC(\bar{\alpha} - 1)}{\mu_bC + (1 - \mu_b)hC}. \quad (5.11)$$

Since $\bar{\alpha}C > R_b$, a loan is repaid when the project succeeds or when the collateral value appreciates. Thus, the bank returns are
\[ h \text{Max}[R_y - r, 0] + (1 - h) \text{Max}[\mu_y R_y + (1 - \mu_y)\bar{\alpha}C - r, 0]. \] (5.12)

The term in the second set of brackets is 0 (Appendix B). In the first brackets, the term is positive if \( R_y > r \). From (5.10) it is possible to observe that this is true if

\[ \mu_y (Y_y - r) - \pi_g - (1 - \mu_y) \left[ C - h(\bar{\alpha}C - r) \right] > 0. \] (5.13)

Since the first term is positive (this is possible to observe from (5.2)), the inequality is satisfied if the second term is sufficiently small. Consequently, the problem of moral hazard may appear also when \( \bar{\alpha}C > R_y \). See Footnote 6 for a numeric example.\(^7\) Maybe surprisingly, the moral hazard problem is avoided if the initial value of collateral is very high.

**Remark 1.** If the initial amount of collateral is very high, for example \( C = r / \bar{\alpha} \), the non-monitoring strategy is unprofitable and the moral hazard problem is eliminated.

To see this, suppose first that \( \bar{\alpha}C < R_y \) and let \( C = r / \bar{\alpha} \). Inserting \( C = r / \bar{\alpha} \) into (5.9) shows that \( \bar{\alpha} \) must be smaller than 1, which is not possible. Suppose now that \( \bar{\alpha}C > R_y \) and \( C = r / \bar{\alpha} \). It is easy to see that constraint (5.13) is not satisfied because \( \mu_y Y_y - r - \pi_g < 0 \).\(^8\)

Consequently, the bank regulator can eliminate moral hazard either by denying the use of collateral, \( C = 0 \), or by imposing very high collateral requirement for banks, \( C = r / \bar{\alpha} \). Only

\(^7\) Suppose that \( \mu_g = 1, Y_g = 1.05, r = 1.03, m = 0.01, Y_y = 1.25, \mu_y = 0.8, h = \frac{1}{7}, \bar{\alpha} = 1.4, \bar{\alpha} = 0.6, C = 0.8 \). Under these values, \( R_G = 1.04, R_y = 1.047 \). When the collateral value appreciates, it exceeds the loan repayment since \( 0.8 * 1.4 = 1.12 > 1.047 \). As a result the bank receives the loan repayment 1.047 when the collateral value appreciates. Since 1.047 > 1.03, the bank makes a profit. Thus, the bank optimally neglects monitoring. When the collateral value depreciates, the total income of the bank, 0.93, does not cover payments on deposits, 1.03, and the bank fails.

\(^8\) This explains why we have excluded \((1 - \mu_y)(1 - h)\text{Max}(0, \bar{\alpha}C - R_y)\) from (5.4). When \( \bar{\alpha}C > R_y \), it is known that \( \bar{\alpha}C > r \) and the non-monitoring strategy is unprofitable.
when the amount of collateral is at the intermediate level, can the problem of moral hazard appear. Intuitively, gambling with collateral is possible only when the initial amount of collateral is at the intermediate level. If the initial amount of collateral is low, $C = 0$, there is nothing to gamble with. If the initial amount of collateral is very high, $C = \frac{r}{\alpha}$, the collateral value is so high that a defaulted loan yields at least $\alpha C = r$, which covers interest on deposits. Thus, the loan is (almost) risk-free; there is no gamble. Furthermore, when the initial amount of collateral is very high, entrepreneurs are ready to borrow only if the loan interest rate is lower than $r$. Then the bank goes into bankruptcy with certainty.

Remark 1, however, underestimates gambling with collateral, since collateral consists entirely of outside collateral. When inside collateral is used, the problem of moral hazard may appear even when the initial amount of collateral is very high. This is explored in section 7.

5.3 Discussion

Diamond (1984) advances a seminal vision on banking. A bank operates as a delegated monitor and financial intermediary. This task generates the moral hazard problem between the bank and its depositors. Will the bank exert effort in monitoring? In Diamond’s model, the problem disappears since the number of borrowers is huge and the risks and returns of their projects are independent. Thanks to the law of large numbers, the loan portfolio is perfectly diversified and its return is certain. Therefore, depositors can rely on the bank being safe.

The initial part of this section follows the vision of Diamond (1984). Thanks to the law of large numbers, the share of successful loans is certain. Thus, without collateral the bank is motivated to monitor borrowers and is risk-free. Thereafter, collateral is introduced. Given the findings of Section 4, it may appear that the bank regulator can be relieved. Two tools, monitoring and collateral, are simultaneously utilized to eliminate moral hazard even through one tool is sufficient. Unfortunately, the appearance is faulty. The introduction of collateral may fuel moral hazard.

Intuitively, without collateral the bank cannot to seek a correlated risk for its loan portfolio. The loan portfolio is perfectly diversified, which eliminates moral hazard. The introduction of collateral changes the state of affairs, since the value of each borrower’s collateral is the same: low or high. Collateral offers a correlated risk to gamble with. It is rather insignificant to the bank whether or not a borrower is able to earn income and thereby repay his loan. Crucial is the collateral value; if it is high, the bank makes a handsome profit, but if it is low, it fails.
There is abundant evidence to suggest that lending decisions are often based on collateral. As to the Savings and Loan Crisis in U.S.A, Freund & Curry & Hirch & Kelly (1998, p. 155) document:

“Traditionally, decisions to extend loans that are collateralized by commercial real estate property are evaluated by lenders primarily on the borrowers’ ability to generate earnings from the investment sufficient to cover the existing debt payments. This is a fundamental tenet of the lending function. As a backup source of security, lenders evaluate the worth of investment property as potential collateral to cover the loan value in the case of default by the borrower. Starting in the late 1970s and continuing for the most of the following decade, examiners observed that lenders loosened loan terms relating to debt-service coverage and placed relatively more emphasis on the value of the collateral in making funding decisions. This change in loan procedures was based primarily on the assumption that real estate values (collateral values) would continue to rise in the future as they had in the recent past. …. When the real estate markets collapsed starting in the late 1980s, many lenders discovered that collateral values were often insufficient to cover existing loan losses”.

The banking crisis in Japan was preceded by similar lending policy. Herring & Wachter (1999, p.40) report: “Some banks apparently tended to rely on the rising value of land rather than rigorous credit analysis in underwriting loans.” Hilberts & Lei & Zacho (2001, p. 14) underline that before the banking crises in Finland and Sweden “lending decisions relied primary on availability of collateral rather than cash flow evaluations.” As regards to the Asian crisis, Collyns and Senhadji (2005, p. 112) note: “Typically, techniques for credit assessment by banks were weakly developed, and banks tended to rely heavily on property collateral (and, to some extent, equity collateral) in making loan decisions.” Consequently, evidence supports the view that many banks neglect monitoring and gamble with the collateral value.
6. Uncertain loan losses, uncertain collateral

Recall that collateral incurs costs to a bank, since a borrower is ready to pledge collateral only if in this way he can cut the loan interest rate. On the other hand, the bank benefits from collateral through unsuccessful loans: when a loan defaults, the bank can seize collateral. The introduction of collateral is profitable to a non-monitoring bank if the second effect dominates. As Section 5 reveals, the second effect dominates if the collateral value fluctuates widely. This section extends the analysis by showing that the second effect may also be prevalent if the upcoming value of collateral is strongly correlated with the upcoming probability of project success. When the collateral value is high, the probability of success is also high and vice versa. Since a thorough examination is complex, the analysis has been shortened considerably. Banking under monitoring, for example, is simplified.

As above, under monitoring (in the absence of monitoring) the upcoming share of successful loans in the loan portfolio is either small, \( n_s(n_n) \), or large, \( n_s(n_n) \), and has an expected value \( \mu_s(\mu_n) \). In addition, the initial amount of collateral is \( C \). Its upcoming value is uncertain and it is either high, \( \bar{\alpha}C \) (with probability \( h \)), or low, \( \alpha C \) (with probability \( 1-h \)). For simplification, suppose that \( n_s = \bar{n}_s = 1 \). Under monitoring, loans always succeed and banks are risk-free. The loan interest rate is \( R = m + r \) and banks earn zero returns. If the expected profits from the non-monitoring strategy are positive, banks optimally neglect monitoring.

In the absence of monitoring, the loan interest rate is such that an entrepreneur is ready to select the bad project. His expected profits are at least the same as from the good project

\[
\begin{align*}
&h P\left( n_s | \bar{\alpha} \right) n_s [Y_s - R_s] - h P\left( n_s | \bar{\alpha} \right) (1 - n_s) \alpha C + \\
&h P\left( n_s | \bar{\alpha} \right) n_s [Y_s - R_s] - h P\left( n_s | \bar{\alpha} \right) (1 - n_s) \alpha C + \\
&(1 - h) P\left( \bar{n}_s | \alpha \right) \bar{n}_s [Y_s - R_s] - (1 - h) P\left( \bar{n}_s | \alpha \right) (1 - \bar{n}_s) \alpha C + \\
&(1 - h) P\left( \bar{n}_s | \alpha \right) n_s [Y_s - R_s] - (1 - h) P\left( \bar{n}_s | \alpha \right) (1 - n_s) \alpha C \geq \pi_o.
\end{align*}
\]

The L.H.S gives the borrower’s profits in four states of the world: high collateral value and large share of successful loans, high collateral value and small share of successful loans, low collateral value and large share of successful loans as well as low collateral value and small share of successful loans. Here \( P\left( n_s | \bar{\alpha} \right) \) ( \( P\left( n_s | \bar{\alpha} \right) \)) denotes the probability that the share of successful
loans is large (small) when the collateral value is high. In addition, \( P(\bar{n}_s | \alpha) (P(n_s | \alpha) ) \) represents the probability, that the share of successful loans is large (small) when the collateral value is low. Obviously, it is known that \( P(n|\alpha) = 1 - P(\bar{n}|\alpha) \) and \( P(\bar{n}|\alpha) = 1 - P(n|\alpha) \). The expected probability of success can now be expressed by summing the expected probabilities of success in the four state of the world

\[
\mu_s = h P(\bar{n}_s | \alpha) \bar{n}_s + h P(n_s | \alpha) n_s + (1-h) P(\bar{n}_s | \alpha) \bar{n}_s + (1-h) P(n_s | \alpha) n_s .
\]

(6.2)

Using (6.2), \( P(n|\alpha) = 1 - P(\bar{n}|\alpha) \) and \( P(\bar{n}|\alpha) = 1 - P(n|\alpha) \), the loan interest, (6.1), can be restated as

\[
R_s = \frac{\mu_s Y_s - \pi_c - [1-n_s - \alpha(\mu_s - n_s)]C + hC P(\bar{n}_s | \alpha)(\bar{n}_s - n_s)(\bar{\alpha} - \alpha)}{\mu_s} .
\]

(6.3)

Here (6.3) reveals that the highest loan interest acceptable to borrowers is maximized when \( P(n|\alpha) \) is as large as possible. Given \( P(n|\alpha) = 1 - P(\bar{n}|\alpha) \), \( P(\bar{n}|\alpha) \) is then as small as possible. Using (6.2), \( P(n|\alpha) = 1 - P(\bar{n}|\alpha) \) and \( P(\bar{n}|\alpha) = 1 - P(n|\alpha) \) it is possible to show that when \( P(\bar{n}|\alpha) \) is maximized, \( P(n|\alpha) \) is minimal. Since \( P(n|\alpha) = 1 - P(\bar{n}|\alpha) \) and since \( P(\bar{n}|\alpha) \) is minimized, \( P(n|\alpha) \) is maximal.

Hence, the loan interest rate is as high as possible when the upcoming share of successful loans (that is, the upcoming probability that a loan succeeds) is closely correlated with the upcoming value of collateral. Intuitively, given the borrower’s participation constraint, collateral cuts the highest loan interest rate that is acceptable to borrowers. This represents the cost of the collateral to the bank. The more severe the borrower’s risk to collateral loss, the larger the required cut in the loan interest rate. When the upcoming collateral value is closely correlated with the upcoming share of successful loans, the costs of collateral are minimized. More specifically, when the value of collateral is high, the probability that a project fails is minimal. It is unlikely that the borrower loses valuable collateral. On the contrary, when the borrower’s project is likely to fail, the collateral value is low. Therefore, even if the borrower loses the collateral, his losses are minor. Thus, the expected costs of collateral are relatively insignificant to the borrower and he is ready to pledge the collateral if the loan interest rate declines slightly. This is, of course, profitable for the banks.
Since the problem is complex, we analyze it with a numeric example. Suppose that
\[ \mu_s = 0.7, \quad n_s = 0.55, \quad \alpha = 0.85, \quad \alpha = 2, \quad h = 0.5, \quad \mu_c = 0.95, \quad r = 1.04, \]
\[ m = 0.01, \quad Y_s = 1.11, \quad Y_s = 1.2, \quad b = 0.5, \quad C = 0.4. \]
The values provide \( \pi_g = 0.0045. \) In this economy, the following inequalities are satisfied
\[
\mu_s R_s(C) + (1 - \mu_s) \alpha C < r, \quad \bar{n}_s R_s(C) + (1 - \bar{n}_s) C < r. \quad (6.4)
\]
The first inequality states that the bank fails when the share of successful loans is at the expected level, \( \mu_s, \) even when the value of collateral is high. That is, the variation in collateral value alone is not sufficient to generate the problem of moral hazard. The second assumption states that the bank fails when the share of successful loans peaks, but the value of collateral is at the expected, average level. Thus, the variation in the share of successful loans alone is not sufficient to cause the moral hazard problem.

First, the probability of success and the collateral value are independent: \( P(\bar{n} \alpha) = \frac{1}{2}. \)

Given (6.3) the loan interest rate is 1.022, which is less than the interest on deposits. Banking is unprofitable. Second, the probability of success and the collateral value are completely correlated: \( P(\bar{n} \alpha) = 1. \) Given (6.3), the loan interest rate is 1.108, which exceeds the interest on deposits. Thus, banking may be profitable. Given (6.4), if the bank can make a profit, it does so when a large probability of success coincides with the high value of collateral. Thus, bank returns amount to
\[
h P(\bar{n} \alpha) Max \left[ 0, \quad \bar{n}_s R_s + (1 - \bar{n}_s) \alpha C - r \right]. \]
Inserting the loan interest rate from (6.3) to this provides rewritten bank returns
\[
h P(\bar{n}_s \alpha) \left\{ 0, \quad \bar{n}_s \mu_s Y_s - \bar{n}_s \pi_g - \mu_s r + \Delta \right\} \mu_s,
\]
\[
\Delta = \left[ -\bar{n}_s + \bar{n}_s \mu_b - \mu_b (\bar{n}_s (1 - \alpha) + \bar{n}_s \bar{n}_s), \quad \bar{n}_s \alpha \right] C + h C P(\bar{n}_s \alpha) \bar{n}_s (1 - \bar{n}_s) (\bar{\alpha} - \alpha) \bar{n}_s
\]

It is easy to see that bank returns are increasing in \( P(\bar{n} \alpha). \) Under the circumstances of the economy, the returns can be expressed as
\[ \frac{1}{2} P(\overline{\alpha}) \left\{ 0, \frac{-0.02 + \left[ -0.1725 + 0.255 \cdot P(n\overline{\alpha}) \cdot C \right]}{0.7} \right\} . \]  

(6.6)

The bank returns are positive only if \( P(n\overline{\alpha}) \) and \( C \) are sufficiently large. When the share of successful loans and the value of collateral are independent, \( P(n\overline{\alpha}) = \frac{1}{2} \), the bank fails. When they are completely correlated, \( P(n\overline{\alpha}) = 1 \), and when the amount of collateral is sufficiently large, e.g., \( C = 0.4 \), banking is profitable without monitoring. Thus, the bank optimally neglects monitoring.

It is important to note from (6.4) that the non-monitoring strategy is unprofitable without collateral. In addition, (6.4) states that the non-monitoring strategy is unprofitable if the collateral value fluctuates, but the share of successful loans is certain. This case (uncertain collateral, certain loan losses) is identical as that described in Section 4, but now the moral hazard problem is now avoided. Only if the share of successful loans also fluctuates, banking may be profitable without monitoring and the problem of moral hazard appears. Consequently, the moral hazard effect of uncertain collateral is strengthened by the uncertain share of successful loans. Furthermore, the larger the correlation between the collateral value and the share of successful loans, the more likely it is that the moral hazard problem appears.

**Proposition 3.** When the volatility of collateral value alone is insufficient to generate moral hazard, the problem of moral hazard may occur if the upcoming share of successful loans also fluctuates. That is, the probability that the collateral value is high simultaneously with the large share of successful loans is sufficiently great.
7. Inside collateral

Let us again repeat the two effects of collateral.

i.) When the initial amount of collateral, \( C \), raises, the loan interest rate has to decline due to the borrowers’ participation constraint

ii.) Unsuccessful loans yield collateral income to banks.

Collateral fuels moral hazard only when the second effect dominates. Section 5 shows that the second effect may dominate when the collateral value fluctuates widely. The first effect – the decline of the loan interest rate – is small, if the initial amount of collateral is not too high. The second effect is strong if the upcoming value of collateral can be high. Section 6 demonstrates that the second effect dominates if the probability of loan success and the collateral value are closely correlated. Then, the first effect is small since the expected loses of the borrower are minimal. The second effect is strong if the upcoming value of collateral can be high. Finally, this section shows that the second effect dominates if collateral consists of inside collateral, which is funded with the loan capital. Since the collateral incurs no costs to borrowers, the first effect is removed and the second effect dominates the first effect.

To model this, the framework is updated. Since an entrepreneur has no capital of his own, he needs to seek for a bank loan. The loan size is 1 unit and is used to purchase assets, which are pledged as collateral, \( C = 1 \) unit. The bank size is 1 and it has no capital of its own. The bank funds its loans by attracting deposits at the interest rate of the economy, \( r \).

The entrepreneur can choose from two project types: a good project or a bad project. When successful, the good project produces \( Y_g \) units. Its expected probability of success is fixed, \( \mu_g \). The bad project succeeds with probability \( \mu_b \) producing \( Y_b \) units, \( Y_b > Y_g, \mu_g > \mu_b \). When unsuccessful, the value of both projects is either \( \alpha C \) or \( \alpha C \) depending on that whether the value of collateral appreciates (with probability \( h \)) or depreciates (with probability \( 1 - h \)) during the project. As before, the expected NPV of the good project is assumed to be clearly positive

\[
\mu_g Y_g + (1 - \mu_g)C > r + m, \quad (7.1)
\]

whereas the expected NPV of the bad project is negative.

---

9 Recall that in Sections 5 and 6, collateral is outside collateral. Outside collateral refers to the case where a borrowing entrepreneur pledges assets not used in the project.
\[ \mu \gamma Y + (1 - \mu) C < r. \quad (7.2) \]

Without monitoring, the risk-shifting problem is assumed to appear. The borrower chooses the bad project since it yields higher expected profits for him

\[ \mu (Y - r) + (1 - \mu) h \text{Max} [0, \alpha C - r] < \mu (Y - r) + (1 - \mu) h \text{Max} [0, \alpha C - r]. \quad (7.3) \]

Note that the borrower cannot lose collateral, since it is purchased with the loan capital. On the contrary, if the collateral value appreciates during the loan period, it exceeds the loan repayment, \( \alpha C > r \), and the borrower receives the surplus, \( \alpha C - r \), even if his project has failed. If a bank monitors (neglects monitoring), a certain share of its loans, \( \mu(\mu) \) is successful. For simplicity, it is assumed that a monitoring bank never fails. That is, \( n_G = \mu = 1 \). As a result, \( R = m + r \) and the expected profits from the good project are \( \pi_g = Y - m - r \).

The bank neglects monitoring if it is profitable. This is possible only if the bank earns profits when the collateral value is high

\[ \mu R + (1 - \mu) \text{Min} [R, \alpha C] > r, \quad (7.4) \]

where \( R \) is solved from the borrowers’ participation constraint. The loan interest rate, \( R \), needs to be such that the borrowers obtain the same expected profits as by choosing the good project

\[ \mu (Y - R) + (1 - \mu) h \text{Max}(0, \alpha C - R) \geq \pi_g. \quad (7.5) \]

Inserting \( R \) from (7.5) into (7.4) gives two scenarios. First, when \( \alpha < R \) (recall \( C = 1 \)) the non-monitoring strategy is profitable if

\[ \mu (Y - r) - \pi_G + (1 - \mu)(\alpha C - r) > 0, \quad (7.6) \]

We show below in a numeric example that the inequality may be satisfied. Second, when \( \alpha > R \), the non-monitoring strategy is profitable if \( R > r \). Given (7.5), this means that
Given (7.3), this is true. Recall from (5.8) that with outside equity moral hazard appears when

\[
\mu_b(Y_b - r) - \pi_G + (1 - \mu_b) h(\tilde{\alpha}C - r) > 0.
\]

The L.H.S is smaller than in (7.6); the moral hazard problem is more severe with inside collateral. Even when the problem of moral hazard is avoided with outside collateral, it may appear with inside collateral. The intuition is obvious. With outside collateral, the borrower faces a risk of losing his own wealth, whereas with inside collateral the borrower cannot lose anything since he has not invested his own wealth in the project. The whole project is funded with the loan capital.\(^{10}\)

The required rise of the collateral value can be small. Suppose an economic environment: \(Y_G = 1.055\), \(r = 1.03\), \(m = 0.01\), \(Y_s = 1.07\), \(\mu_b = 0.6\), \(h = \frac{1}{2}\), \(\tilde{\alpha} = 1.03\), \(\alpha = 0.97\). Under these economic circumstances, \(R_s = 1.045\). Because \(1.03 < 1.045\), the appreciated value of collateral does not cover the loan repayment and a borrower receives income only if the project succeeds. Since \(0.4 \times 1.045 + 0.6 \times 1.03 = 1.036\), the bank’s income covers payments on deposits 1.03 when the collateral value appreciates. Therefore, the bank is profitable if the collateral value appreciates even when the share of successful loans is small, 40%, and the rise of the collateral value is modest, 3%. The problem of moral hazard appears.

**Proposition 4.** The moral hazard problem is less severe with outside collateral than with inside collateral (when the whole project is financed with the loan capital).

This section can be interpreted as follows. A borrower purchases a house, which is pledged as collateral. If the borrower can earn income, he can repay the loan and keep the house. If he cannot earn income, the bank seizes the collateral. However, since the value of the house can appreciate

\(^{10}\) Note from (7.6) and (7.7) that the larger the reservation utility of the borrower, \(\pi_G\), the lower the loan interest rate is. Hence, if there are loan applicants with different reservation utilities, a bank, which is gambling with the collateral value, may optimally choose “bad loan applicants” with a low reservation utility because these are ready to pay high interest on loans.
during the loan period, it is possible that its value exceeds the loan repayment. Then, the borrower can keep the surplus. The borrower decides whether to work hard (choose a good project) or shirk effort (choose a bad project). Again, the bank is gambling with collateral. If the value of the house appreciates sufficiently, \( \alpha C > R_s > r \), the bank does not bear loan losses even when it does not monitor its borrowers. If the property value depreciates, a large share of borrowers cannot repay their loans and the bank fails.

8. Conclusion

This paper has explored how collateral affects bank risk. We have seen that if the collateral value is certain, the introduction of collateral alleviates the volatility of bank returns, thereby making banks more safe and mitigating moral hazard. If the value of collateral fluctuates, the introduction of collateral may generate a moral hazard problem. This negative effect of collateral may deepen if the value of collateral is strongly correlated with the project’s probability to success. The negative effect is also deepened if collateral consists of inside collateral, which is financed with the loan capital.

We do not insist that collateral is the main cause of the recent banking crises. However, we argue that in some cases, for example in the subprime mortgage crisis and in emerging economies, collateral may have played a crucial role. Subprime mortgage lending satisfies the conditions that induce moral hazard: collateral value fluctuates strongly, it is correlated with the probability to earn income and collateral consists mostly of inside collateral, which is funded with the loan capital.\(^{11}\) Furthermore, the borrowers of subprime banks are risky clients willing to pay high interest on loans. Thus, it is likely that the problem of moral hazard appears. A few subprime banks relying on the rising value of real estate have granted loans to loan applicants without attempts at borrower evaluation.

---

\(^{11}\) In many cases, a loan-to-value ratio is over 90% (Chomsisengphet & Pennington-Cross, 2006).
Appendix A

Appendix A solves the variance of the collateral value as a function of $\bar{\alpha}$.

Using the definition of variance, $\sigma^2(X) = E(X^2) - [E(X)]^2$, the variance of the collateral value can be expressed as

$$\sigma_c^2 = h(\bar{\alpha}C)^2 + (1-h)(\bar{\alpha}C)^2 - [C]^2$$

$$= C^2 \left\{ \frac{h\bar{\alpha}^2}{1-h} + (1-h) \left[ \frac{1-h\bar{\alpha}}{1-h} \right]^2 - 1^2 \right\}$$

$$= \left( h\bar{\alpha}^2 - 2h\bar{\alpha} + h \right) \frac{C^2}{1-h} \tag{A.1}$$

It is easy to see that the variance is increasing in $\bar{\alpha}$, since $\bar{\alpha} > 1$ Q.E.D

Appendix B

This Appendix shows that the term in the second set of brackets of (5.12) is zero. To see this, note that $\mu_y R_y + (1-\mu_y)\bar{\alpha}C - r$ can be rewritten as $\mu_y Y_y - r - \pi_g + (1-\mu_y)h(\bar{\alpha}C - R_y)$. This is negative at least when $\bar{\alpha}C < R_y$. To see that $\bar{\alpha}C < R_y$, we express (5.10) as follows

$$(1-\mu_y)(1-h)(\bar{\alpha}C - R_y) + (R_y - r) = \mu_y Y_y - \pi_g - r. \tag{B.1}$$

The R.H.S is negative. There are two terms on the L.H.S. The latter is positive, when the non-monitoring strategy is profitable. If $\bar{\alpha}C > R_y$, the first term on the L.H.S is also positive. But then the L.H.S is positive and the R.H.S is negative, which is not possible. Thus, it is known that $\bar{\alpha}C < R_y$ and the term in the second brackets of (5.12) is equal to zero; the bank fails when the collateral value depreciates. Q.E.D
References


