# Working Paper

What determines banks' market power? Akerlof versus Herfindahl

by

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# What Determines Banks' Market Power? Akerlof versus Herfindahl*

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**Abstract**

We introduce a model analyzing how asymmetric information problems in a bank-loan market may evolve over the age of a borrowing firm. The model predicts a life-cycle pattern for banks' interest rate markup. Young firms pay a low or negative markup, thereafter the markup increases until it falls for old firms. Furthermore, the pattern of the life-cycle depends on the informational advantage of the inside bank and when more dispersed borrower information yields fiercer bank competition. By applying a new measure of the informational advantage of inside banks and a large sample of small Norwegian firms, we find empirical support for the predicted markup pattern. We disentangle effects of asymmetric information (Akerlof effect) from effects of a concentrated banking market (Herfindahl effect). Our results indicate that the interest rate markups are not influenced by bank market concentration.

# 1. Introduction

We analyze how competition and asymmetric information problems are interlinked in credit markets. During the course of a lending relationship a bank obtains privileged information about borrowers. The privileged information is a two-edged sword seen from borrowers' point of view. Privileged information reduces frictions in credit markets, but creates lock-in effects and market power for the inside bank, i.e., the bank with which the firm has a relationship.

One of the contributions of this paper is in offering a dynamic model of bank-borrower relationship that evolves over three distinct periods in the life cycle of the borrowing firm. Initially, before any bank has obtained privileged information about young firms, they are offered loans with a low or even negative interest rate markup. By interest rate markup we mean the difference between the actual contractual interest rate and the risk-adjusted interest rate, i.e., the one that gives the lender zero expected profits. As the firm's inside bank gets access to privileged information about the borrowing firm, it becomes informationally locked-in and the bank can extract rents by increasing the interest rate markup. However, as the firm matures, specific soft information about the firm gets more dispersed. Consequently the market power of the inside bank decreases, as outside banks now find it profitable to monitor the borrower and offer loans. Hence, the markup is reduced. The existing theoretical literature on relationship lending and informational lock-in only deals with two distinct periods, the initial period when the borrower is subsidized and the second period when he is locked-in.[1] In contrast, our model can also explain how informational lock-in is resolved.

The model predicts that this pattern of the interest rate markup over a firm's life cycle will be more pronounced the more important is the soft information the inside bank can obtain, i.e., the larger is the information asymmetry between the inside bank and the outside banks. We test this and other predictions of our model using panel data of small Norwegian non-financial firms during the 2000-2001 period with a total of 60,362 observations. We construct a novel measure proxying the importance of the information asymmetry.

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[1] See for instance Rajan (1992), Sharpe (1990) and, von Thadden (2004).

This paper focuses on the importance of information asymmetries in determining banks' market power in credit markets characterized by relationship lending. It is the degree of asymmetric information and the consequent lack of competition that determines to what extent banks intertemporally share their surplus in long-term bank relationships. This approach differs from that of Petersen and Rajan (1995). In their much cited paper, Petersen and Rajan also construct a model where lack of competition in the credit markets allows banks to subsidize young de novo firms and recapture this loss by charging older locked-in borrowers an interest rate above the one yielding them zero expected profits. However, in Petersen and Rajan (1995) lack of competition in the credit market is represented by the degree of market concentration (Herfindahl). Our study differs from Petersen and Rajan in the sense that we let the competitiveness of the credit market be determined by the availability of soft information about the borrowers (Akerlof). In the empirical setup we are able to test simultaneously whether intertemporal surplus sharing through long-term bank relationships is determined by the degree of information asymmetry between the inside bank and outside banks, or by the concentration in credit markets as in Petersen and Rajan (1995). Our results indicate that the former is the determining factor rather than the latter.[2]

In our theoretical model the number of banks that monitor a borrower and thereby the strength and time-span of the lock-in effect are endogenized. This model is closely related to other models also explaining how firms can mitigate hold-up problems or lock-in effects by establishing several bank relationships.[3] However, these models focus on situations where firms decide, in the first period, on the number of bank relationships. In contrast, our setup makes multiple monitoring of young firms unprofitable. We argue that fixed monitoring costs cannot initially

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[2]There are other empirical papers that also check the robustness of some of the findings by Petersen and Rajan, although with a different approach from ours. All in all these studies seem to give mixed results. Black and Strahan (2002) find that less concentrated banking markets lead to more incorporations of new firms, thus casting doubts on Petersen and Rajan's findings. Similarly Cetorelli (2004) finds that a more concentrated banking industry leads to larger size of the non-financial firms. Cetorelli and Gambera (2001), however, report results indicating that younger firms relying on external finance grow faster the more concentrated is the banking sector. A brief overview of this literature can be found in Berger, Hasan, and Klapper (2003).

[3]Ongena and Smith (2000) show in an empirical study, that multiple relationships reduce the hold-up problem, but can worsen the availability of credit. See also Detragiache, Garella, and Guiso (2000).

be covered by more than one bank. Other researchers have argued that multiple monitoring is infeasible due to free-riding problems (Thakor (1996)).[4] We show that as firms mature, more banks (or other monitors) find it profitable to monitor them and thereby alleviate firms' hold-up or lock-in problem. Existing literature allows firms to determine the number of banks from which they borrow. In contrast, we let improvements in the pool of loan applicants as the firms mature and the accordingly increased bank competition determine when lock-in problems are resolved.

There is a growing literature arguing that competition intensity also influences banks investments in borrower-bank relationships. Boot and Thakor (2000), Elsas (2005), Dell'Ariccia and Marquez (2004), and Degryse and Ongena (2004) all show that competition may have an important impact on banks' investments in industry expertise and relationship development. If fiercer competition induces banks on average to provide more valuable services to their borrowers, we might expect to see that equilibrium interest rates are higher in more competitive markets. Boot and Thakor (2000) show in their theoretical model how fierce bank competition may induce banks to substitute transactional lending with relationship lending thereby insulating a larger share of their loan portfolio from competition induced by rivalling banks. The average borrower may, due to this substitution effect, increase his willingness to pay high interest rates. In the empirical part of the present study, we are also able to examine whether competition, measured as market concentration, increases borrowers' willingness to pay high interest rates.

The paper is organized as follow: In Section 2 we present a theoretical model showing how the severity of asymmetric information affects borrower lock-in and hence competition between banks and interest rate markups. The empirical model testing both the predictions regarding markups and asymmetric information emanating from our theoretical model, as well as the aforementioned potential relationships between markups and market concentration, is presented along with the data in Section 3. The empirical results are presented and discussed in Section 4. Section 5 concludes.

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[4]Carletti (2004) endogenizes banks' monitoring intensities and shows how firms by choosing to borrow from more than one bank can induce a preferred monitoring intensity. In contrast to our model, Carletti does not introduce a dynamic model that allows the number of monitoring banks to change as the firms mature.

## 2. Theory

In this section we introduce a theoretical model of bank competition that shows how the lifecycle of the interest rate markup depends on two types of asymmetric information problems. Firstly, there is an asymmetric information problem between banks and borrowers and, secondly, there is a potential asymmetric information problem between inside and outside banks when they "bid". The model endogenizes the number of monitoring banks in order to show how firm specific information gets dispersed and lock-in effects weaken. The theoretical model allows us to derive predictions about how the two types of asymmetric information problems influence the length of the lock-in period and the timing and size of the minimum and maximum interest rate markup charged by banks.

In what follows we outline the model in detail.

### 2.1. The borrowing firm

A firm is modelled as a sequence of projects all requiring investment of 1. For simplicity, we assume that the firm does not have own funds and needs to borrow 1 from a bank in each period $t$, $t \geq 0$ (see Rajan (1992) for why asymmetric information problems may imply that only short-term loan contracts are used in equilibrium).

In our adverse-selection model, a project in each period is either good or bad independently of the quality of the previous project. The *good* project succeeds with probability $\theta + \beta$ while the *bad* project succeeds with probability $\theta - \beta$. A successful project is worth $R$ while a failure is worth 0. Apart from Proposition 4 which concerns credit availability, we assume that both good and bad projects have positive NPV, i.e., $(\theta - \beta) R > 1$. The probability of having a good project in period $t$ is common knowledge and denoted $s(t)$. We assume that the average quality of borrowers is improving as the firms mature ("survival of the fittest"), i.e., $s'(t) > 0$. Consequently, we assume that experienced firms are more likely to have good projects than young and unexperienced firms.

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## 2.2. Banks

There are two banks that consider monitoring the firm.[5] Let $F > 0$ denote per-period monitoring cost. Although, monitoring cost incurs in each period, we assume that monitoring decisions are long-term commitments; a monitoring bank will continue to do monitoring although a rivaling bank starts monitoring. Furthermore, it is assumed that $F$ is sufficiently large compared with expected profit to make it unprofitable for *both* banks to start monitoring in period 0. The inside bank monitors the firm and with probability $\lambda$ it is revealed to the bank whether the project is good or bad. The outside and inside banks both have access to the same information about the project with probability $(1 - \lambda)$. Notice, however, that the outside bank does not know whether the inside bank has obtained privileged information or not. An outside bank knows only the probability of the firm being of a good type, i.e. $s(t)$.

The competition between the two banks is considered as an "English auction" where banks decrease their interest rates until one bank is active and this bank captures the borrower. If the two banks' lowest interest rates are identical and they both monitor the borrower, they capture the borrower with equal probability. If only one bank does monitoring, the borrower will weakly favour the existing lender. This assumption ensures that, in equilibrium, there will not be change of lenders as long as only one bank does monitoring, but the rivaling outside bank limits the interest-rate markup the inside bank can obtain.[6]

For simplicity, we assume that firms and banks are risk neutral and that the risk-free interest rate is 0.

In our set up banks know that the average quality of borrowers is improving as the borrowers age and this makes it increasingly attractive for banks to bear the fixed monitoring costs and make credit assessment in order to make loan offers. When a second bank starts making credit assessments, information about borrowers

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[5]We endogenize when the second bank starts monitoring. A straight forward generalization of our model would be to endogenize when $n > 2$ banks start monitoring.

[6]In an English auction an auctioneer starts with a high interest rate and gradually decreases it. The current interest rate, $r$, is observed by all banks (bidders) and the banks choose whether to be in the competition or to exit. Banks may drop out at any time, and if they do they are not allowed to reenter the competition (auction) for the borrower. When the auction ends there is only one active bank. See Krishna (2002) for a discussion of different rules in English auctions.

success probabilities becomes more dispersed and bank competition increases. In the next section we examine the market equilibrium in detail.

## 2.3. Equilibrium

We will show that there exists a pure strategy subgame perfect Nash equilibrium where one bank lends to and monitors a firm from date 0 and the second bank starts monitoring at date $T > 0$. Let $\pi$ denote the profit obtained by the first bank until the second bank start monitoring ($\pi$ will be analyzed subsequently).

In equilibrium the banks set their interest rates, $r^e$, as described by Proposition 1.

**Proposition 1.**

*i) At $t = 0$ both banks offer interest rates that will remove all long term profit*

$$r^e \left( t = 0 \right) = s(0)\frac{1}{\theta + \beta} + (1 - s(0))\frac{1}{\theta - \beta} - \pi - 1.$$

*ii) At $t \in [1, T - 1]$ the outside bank expects to capture only bad projects and offers interest rates, $r^e$, reflecting the risk of bad projects*

$$r^e \left( 1 < t \leq T - 1 \right) = \frac{1}{\theta - \beta} - 1$$

*and the inside bank will keep the borrower by offering the same interest rate as the outside bank.*

*iii) At $t \in [T, \infty\rangle$ both banks may acquire privileged information. Interest rate charged a borrower having a good project depends on whether more than one bank has this information (probability $\lambda^2$),*

$$r_G^e \left( T \leq t \right) = \begin{cases} \frac{1}{\theta + \beta} - 1 & \text{with probability } \lambda^2 \\ \frac{1}{\theta - \beta} - 1 & \text{with probability } 1 - \lambda^2 \end{cases}$$

*while the interest rate charged a borrower with a bad project reflects its credit risk*

$$r_B^e \left( T \leq t \right) = \frac{1}{\theta - \beta} - 1$$

**Proof.** Part i): Straightforward.

Part ii): Note that the bidding behaviour of the informed inside bank is such that its lowest bid implies zero profit. The outside bank will correctly expect that

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it only will capture borrowers with bad projects if it improves its interest rate bid from $r = \frac{1}{\theta - \beta} - 1$ and this will make a better interest bid nonprofitable.

Part iii): The same argument as for Part ii) can be applied for Part iii). ∎

Proposition 1 describes bank competition taking the second bank's monitoring decision as given ($T$ is taken as given). We will now analyze $T$ and study when the second bank starts monitoring. First, note that the second bank's expected one-period profit is

$$\lambda (1 - \lambda) s(t) \left\{ (\theta + \beta) \frac{1}{\theta - \beta} - 1 \right\} - F$$

or

$$\lambda (1 - \lambda) s(t) \left\{ \frac{2\beta}{\theta - \beta} \right\} - F$$

if it monitors. In the above expression, $\lambda (1 - \lambda)$ denotes the probability of obtaining exclusive privileged information, $s(t)$ is the probability that the project is good and succeeds with probability $(\theta + \beta)$. In case of success, the firm is able to pay the face value of debt which is $\left( \frac{1}{\theta - \beta} \right)$ if the other bank fears that the borrower has a bad project.[7]

The second bank finds it profitable to start monitoring when the per-period profit exceeds the monitoring costs. More formally, the following condition (2.1) describes when the second bank starts monitoring ($T$).

$$\lambda (1 - \lambda) s(T) \left\{ \frac{2\beta}{\theta - \beta} \right\} > F > \lambda (1 - \lambda) s(T - 1) \left\{ \frac{2\beta}{\theta - \beta} \right\} \tag{2.1}$$

Condition (2.1) states that it is non-profitable to start monitoring in period $T - 1$ but profitable in period $T$. Since $s'(t) > 0$ it follows that $T$ is uniquely defined by condition (2.1).

We can now calculate the profit from capturing the borrower in period 0 instead of waiting until period $T$ and then start monitoring;

$$\pi = \frac{2\beta}{\theta - \beta} \sum_{t=1}^{t=T-1} s(t) - TF$$

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[7]The inside bank offers a loan contract that makes the entrepreneur indifferent between accepting the contract from the inside bank and accepting the contract from the outside bank. Since the outside bank offers a contract reflecting that only the low type borrowers will switch banks, the difference is $\left( R - \left( R - \frac{1}{\theta - \beta} \right) \right) = \frac{1}{\theta - \beta}$.

In a competitive bank-loan market (Bertrand competition) where banks expect to profit from long-term bank-borrower relationships, banks price their initial loans at date 0 very aggressively in order to attract new borrowers. Competition at date 0 drives the interest rate down until the winning bank spends the entire anticipated profits ($\pi$) to subsidize the initial loan.

We can now compare the equilibrium interest rate with the interest rate yielding zero-bank profit provided that the bank has only access to public information. Denote this benchmark interest rate $r^*(t)$,

$$r^*(t) = s(t)\frac{1}{\theta + \beta} + (1 - s(t))\frac{1}{\theta - \beta} - 1. \tag{2.2}$$

Note that $r^*(t)$ is decreasing as the quality of the average borrower improves, i.e. $s(t)$ increases. The markup on the benchmark interest rate in period $t$ is $m_t = r^e(t) - r^*(t)$. From the definition of $r^*(t)$ and Proposition 1 it follows directly that:

**Proposition 2.** *The markup, $m_t$, follows a life cycle pattern;*

    *i) in period $t = 0$, we have $m_t < 0$*

    *ii) in the following periods, $t \in [1, T - 1]$ , $m_t$ is increasing in $t$.*

    *iii) in period $T$, we have $m_T < m_{T-1}$.*

Note that the equilibrium interest rate at $T-1$ is $\frac{1}{\theta - \beta} - 1$, while at $T$ it decreases to $\left(1 - \lambda^2 s(t)\right)\frac{1}{\theta - \beta} + \lambda^2 s(t)\frac{1}{\theta + \beta} - 1$ where $\lambda^2 s(t)$ is the probability that both banks have discovered that the project is good.

In Proposition 3 we show that the life cycle of the markup may depend on the size of the monitoring costs which we associate with the prevalence of asymmetric information problems in the credit market. Firms with more asymmetric information problems and, consequently, higher monitoring costs may have a different markup cycle than firms with lower monitoring costs.

**Proposition 3.** *Firms with high monitoring costs $(F)$,*

    *i) have a longer lock-in period $(T)$ than firms with low monitoring costs.*

    *ii) have a higher maximum markup $(m_T)$ than firms with low monitoring costs.*

**Proof.** Part i) follows directly from (2.1) and the assumption that $s'(t) > 0$.

Part ii): Note that the markup for period $t \in [1, T-1]$ is given by

$$
\begin{aligned}
m_t &= \left( \frac{1}{\theta - \beta} - 1 \right) - \left( s(t-1) \frac{1}{\theta + \beta} + (1 - s(t-1)) \frac{1}{\theta - \beta} - 1 \right) \\
&= \frac{2\beta}{(\theta + \beta)(\theta - \beta)} s(t-1)
\end{aligned}
$$

and that $s'(t) > 0$. Part ii) follows from observing that $m_t$ reaches its maximum at $t = T - 1$ and that $T$ is increasing in $F$ (follows from part i). ■

Not only markups but also *credit availability* may depend on asymmetric information problems in credit markets. In order to focus on potential effects on credit availability we will allow firms to have negative NPV projects in the first period. Consequently, some firms will be unable to obtain funding in period 0 unless banks expect to gain from long-run bank-borrower relationships. We divert from the set up above by making one new assumption; in the first period the success probability is between 0 and 1, or more formally in period 0 we let $\theta = \theta_0 \in [\beta, 1 - \beta]$. A bank is willing to lend to all borrowers in period 0 with $\theta_0 > \hat{\theta}$ where $\hat{\theta}$ is defined by

$$
1 = \underbrace{s(0) \left( \hat{\theta} + \beta \right) R + (1 - s(0)) \left( \hat{\theta} - \beta \right) R}_{\text{Expected pay back on the first loan}} + \underbrace{\Pi}_{\text{Long run gain}}
$$

where $\Pi$ is total profit banks expect to earn on a borrower (may contain profit after the lock-in period ends). A bank is willing to lend the borrower 1 dollar – although the expected pay back on the initial loan is low – as long as the long run-gain from establishing a bank-borrower relationship is sufficiently large. By observing that a longer lock-in period increases $\Pi$, we have Proposition 4:

**Proposition 4.** *A bank accepts borrowers with lower first-period success probabilities (lower $\hat{\theta}$) if the profits from lock-in, $\Pi$, increases.*

In the empirical section to follow, we show how the asymmetric information problems and lock-in effects evolve for a large sample of Norwegian firms.

## 3. Empirical investigation

### 3.1. Hypotheses and modelling

In this section we specify an empirical model in order to test the empirical implications or hypotheses derived from the theoretical model in section 2:

**I** The interest rate markup follows a life cycle pattern over the firm's age: young firms pay a low or negative markup, thereafter the markup increases until it falls for old firms (see Proposition 2).

**II** The life cycle pattern described in I is more pronounced for more opaque firms, i.e., firms with more severe asymmetric information problems (see Proposition 3 ii).

**III** Banks will on average lend to firms with higher bankruptcy probability if the lock-in effect is stronger (see Proposition 4).

**IV** More opaque firms have a longer lock-in period (see Proposition 3 i).

Unlike the existing literature, our empirical model allows us to distinguish effects originating from asymmetric information from those originating from market concentration. In their much cited paper, Petersen and Rajan (1995) examine pricing and credit availability associated with the degree of competition in credit markets, measured as market concentration. They introduce a theoretical model which they use to show how credit availability and intertemporal pricing of loans may depend on market concentration. Consistent with their theoretical model they find that concentrated credit markets allow banks to take a loss initially in order to benefit from a long-term relationship with a borrower. In Petersen and Rajan (1995) market concentration determines to what extent firms can establish long-term relationships. In contrast, we examine directly whether asymmetrically dispersed information between inside and outside banks is crucial for establishing long-term bank relationships. It is the informational advantage of the inside bank that reduces competition and allows the bank to intertemporally share its surplus in a long-term bank relationship. In order to make our study comparable with Petersen and Rajan

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(1995) we introduce market concentration variables in addition to asymmetric information variables. In this way we can examine whether market concentration has a separate effect on the intertemporal pricing of loans (see Hypothesis V below).

Petersen and Rajan (1995) assume that bank loans are homogenous. In contrast, Boot and Thakor (2000) suggest that banks may change their type of lending when the competitive environment changes. They present a theoretical model where banks strategically choose how much of their lending they want to do as transaction based lending compared with relationship lending. Relationship lending increases the success probability of borrowers projects and therefore makes borrowers willing to pay higher interest rates. If reduced market concentration induces banks to provide more valuable relationship loans, interest rate markups may increase as markets get less concentrated[8]. This suggests Hypothesis VI below. To summarize, by including a market concentration measure in our empirical model we are able to also test the following two opposing hypotheses:

**V** Reduced market concentration leads to lower interest rate markups for mature firms and higher markups for *de novo* firms. This effect of market concentration on interest rate markup will lend support to the findings by Petersen and Rajan (1995).

**VI** Reduced market concentration leads to higher interest rate markup for an average borrower. Assuming higher interest rate markups in relationship banking compared with transaction based banking, this finding may lend support to Boot and Thakor (2000).

To test the above hypotheses I to VI, we present an econometric model with the actual interest rate markup (i.e., the actual interest rate minus the risk adjusted zero expected profits interest rate) paid by firms as the LHS variable. For RHS variables we use the age of the firm (represented by two dummies for three different age groups: young, middle aged, and mature firms), a variable representing the degree of asymmetric information, and a variable measuring market concentration in the different credit markets covered by the data.

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[8]We are not able to *ex ante* separate transaction based borrowers from relationship borrowers in our sample. However, such a separation is not necessary when one can assume that there are higher interest rate markups in relationship banking compared with transaction based lending.

We specify the risk-adjusted zero-expected profits interest rate as the interest rate a borrowing firm would pay in a world with a risk neutral competitive banking industry in the following way:

$$1 + r_{f,t} = p_{i,t}(1 - LGB) + (1 - p_{i,t}) \cdot (1 + r_{i,t}^*)$$
$$r_{i,t}^* = \frac{r_{f,t} + p_{i,t}LGB}{1 - p_{i,t}}$$

where $r_{f,t}$ is the risk-free money market interest rate, $p_{i,t}$ is the probability at time $t$ that firm $i$ will go bankrupt, $LGB$ is the loss given bankruptcy, i.e., the fraction of the principal of the loan that the bank will have to write off in case of bankruptcy.[9] $r_{i,t}^*$ is then defined as the risk-adjusted interest rate.

Our LHS variable, the interest rate markup is thus

$$m_{i,t} = r_{i,t} - \overline{r_{i,t}^*} \quad , \tag{3.1}$$

where $r_{i,t}$ is the actual interest rate firm $i$ pays in year $t$. $\overline{r_{i,t}^*}$ is the average of the risk-adjusted interest rate for year $t$ based on the bankruptcy probability $p_{i,t-1}$ and the risk-adjusted interest rate for year $t$ based on the bankruptcy probability $p_{i,t}$. In both cases the risk-free interest rate for year $t$, $r_{f,t}$ is used. Our motivation for using this average is the fact that during year $t$ only the information from balance sheet and income statements for year $t-1$ are publicly available. However, a bank lending to a firm in year $t$ will also seek current information from the firm's books to further help assessing the bankruptcy probability of the firm.

The general form of our empirical model is

$$m_{i,t} = (AINFO, \mathbf{d}_{AGE;i,t}, concentration, \epsilon_{i,t}) \quad , \tag{3.2}$$

$AINFO$ is a variable representing the severity of asymmetric information. $\mathbf{d}_{AGE;i,t}$ is a vector of the dummies representing the age group for firm $i$ in year $t$. It will

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[9]In the actual empirical model LGB is set at 0.6. The Basel Committee suggests in its Third Consultative Paper, Basel Committee on Banking Supervision (2003), that loss given default (LGD) is set to 45% for senior unsecured debt and 75 % for subordinated claims without specific collateral (the IRB Foundation approach). Note however that we look at bankruptcy which is more 'severe' than default.

enable us to test how the interest rate markup differs between firms of various ages. *concentration* captures the degree of concentration in the credit market from which the firm demands credit. $\epsilon_{i,t}$ is the stochastic residual.

## 3.2. Data

Our data are collected from the SEBRA-database covering all limited liability firms in Norway.[10] This database contains annual financial statements (balance sheets and income statements) from 1988 to 2001. It also contains information about firms' characteristics such as the industrial sector code, the geographical location of the firms' head offices, and firms' age. In addition, we apply results from a model predicting bankruptcy probability for each firm and each year (see Appendix B). In this model, bankruptcy is defined as the event in which a firm declares itself bankrupt within the next three years. The predicted bankruptcy probabilities from the model are added to the database.[11] In our empirical model we use these predicted bankruptcy probabilities.

From year 2000 the SEBRA-database allows us to separate bank loans from other debt. Hence, we use data from year 2000 and 2001. The database contains information for approximately 130,000 firms each year, and initially we are left with a quarter of a million observations. Of those, however, we only consider non-financial firms. Since we are particularly interested in the asymmetric information aspect in relationship lending we have removed firms that have issued bonds and thus often have a bond rating. Furthermore we drop firms that either lend to or borrow from other companies in a conglomerate. Lending inside a conglomerate is not associated with significant asymmetric information problems. We also exclude large firms, those with an annual operating income above 100 NOK million, leaving us with a sample of rather small firms, firms about which there is little public information.

Actual paid interest rates are calculated from firms' income statements and balance sheets by dividing each firm's interest cost by the unweighted average of bank loans outstanding at the end of year $t - 1$ and $t$.[12] Since most loans extended by

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[10]The SEBRA-database is owned by Norges Bank (The central bank of Norway), and is based on data supplied and quality tested by Dun and Bradstreet.

[11]This model is described in Eklund, Larsen, and Bernhardsen (2001), and a more comprehensive description is given in Bernhardsen (2001).

[12]Some firms have large changes in their lending during the beginning or the end of the year. This

Table 3.1: Summary statistics

| Variable | Mean | Std. Dev. | Min. | Max |
|---|---|---|---|---|
| Operating income | 5921 | 10409.4 | -4607 | 99661 |
| Total assets | 5529 | 14992.23 | 0 | 665162 |
| Bank debt to total assets | .75 | 11.56 | 0 | 1771 |
| Interest rate | 0.117 | 0.0426 | 0.06 | 0.2499 |
| Interest rate markup | 0.0265 | 0.0563 | $-1.242$ | 0.1795 |
| Probability of bankruptcy | .02431 | .05143 | .00006 | .68401 |
| Firm age | 11.2 | 13.1 | 0 | 149 |

Number of observations is 60,362. Operating income and total assets are measured in NOK thousands. Bank debt to total assets is measured as a ratio. Interest rate and interest rate markup are also measured as ratios. Probability of bankruptcy, measured as a ratio, is predicted from the SEBRA model. Firm age is measured in years.

Norwegian banks have a floating interest rate, we believe our approach of calculating interest rate is more accurate than interest rates that can be collected from loan contracts annually. In 2000 and 2001 the central bank changed its deposit rate five times and one time, respectively. Contractual interest rates observed once a year would not capture these changes in interest rates. By calculating the interest rates using the interest cost for the whole year, we implicitly include the intra-year changes of interest rates.

Our panel then consists of 35,423 firms in 2000 and 24,939 firms in 2001. Of these 24,939 firms 24,520 are observed in both years. Table 3.1 gives a summary of some of the interesting characteristics of the firms in the sample.

Table 3.1 illustrates that there is a considerable firm heterogeneity in the sample. 3,094 of the firms have zero bank debt by the end of one of the years. Of the 60,362 observations 6.4 pct. of the firms have bank debt to total assets larger than unity. i.e., they are technically, but not necessarily legally bankrupt. This variation in

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leads to unrealistically low or high calculated interest rates for those firms. Such phenomena occur more frequently for larger firms. That is one further motive for excluding from the sample large firms, defined as firms with annual sales in excess of NOK 100 million corresponding to appr. EUR 12.5 million. This leaves out 5203 observations or 8.6 pct. of the final number of observations. We also exclude remaining observations with pathological interest rates. In an empirical work also based on the SEBRA-database Bernhardsen and Larsen (2003) use the same procedure for calculating firm borrowing interest rate. In their paper they find strong evidence that this a reasonably accurate measure of the interest rate borrowing firms face.

the probability of bankruptcy to some extent also spills over to the interest rate markup. There are a few firms in the sample with large negative markups. These are firms with high bankruptcy probabilities for which the risk-adjusted interest rates are correspondingly high. Large negative markups can be due to banks aggressive pricing of loans to new borrowers as suggested by our theory model.[13]

There is also considerable variation in the age of firms. The average firm in the sample is just below 12 years, and the oldest firm is 149 years. The age distribution in the sample is illustrated in Figure 3.1.

Figure 3.1 shows that the peak age of firms in our sample is 3 years. The median age is 7 years and the mean just above 11 years. This skewed distribution is typical for the age of firms in large samples. Many of the relatively young firms will not survive as independent entities because they go bankrupt, are closed before bankruptcy, or are acquired by other firms. Nevertheless 7,646 or 12.7 pct. of the observations in the sample relate to firms 20 years or older.

We suggest a novel measure of the severity of asymmetric information problems between inside and outside banks. In line with our theoretical model, we assume that an inside bank obtains information about firms credit worthiness before outside banks. This information advantage of inside banks is particularly valuable in industries where firms' credit worthiness change quickly. Hence we propose the volatility of bankruptcy probability in the industry to which the firm belongs, as a measure of the inside banks' information advantage over outside banks. Figure 3.2 illustrates the change in bankruptcy probability for three different firms in our sample.[14] Consider a firm belonging to an industry where firms' bankruptcy probabilities and credit ratings vary considerably over time. Soft information about firms' prospects acquired through a bank relationship is particularly valuable in such industries. This

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[13]Alternatively, a large negative markup can be due to firms' moral hazard problems which prevent banks from increasing the interest rate (see Stiglitz and Weiss (1981) and Williamson (1987)).

[14]For the high volatility firm in Figure 3.2 the volatility of bankruptcy probability is just below the 95 pct. fractile. For the low volatility low bankruptcy probability firm both the bankruptcy probability and its volatility are below the 5 pct. fractile. The low volatility high bankruptcy probability firm has for three consecutive years a bankruptcy probability around the 85 pct. fractile, its bankruptcy probability falls and after a few years remains below the lower quartile. Its volatility, however is around the 15 pct. fractile.
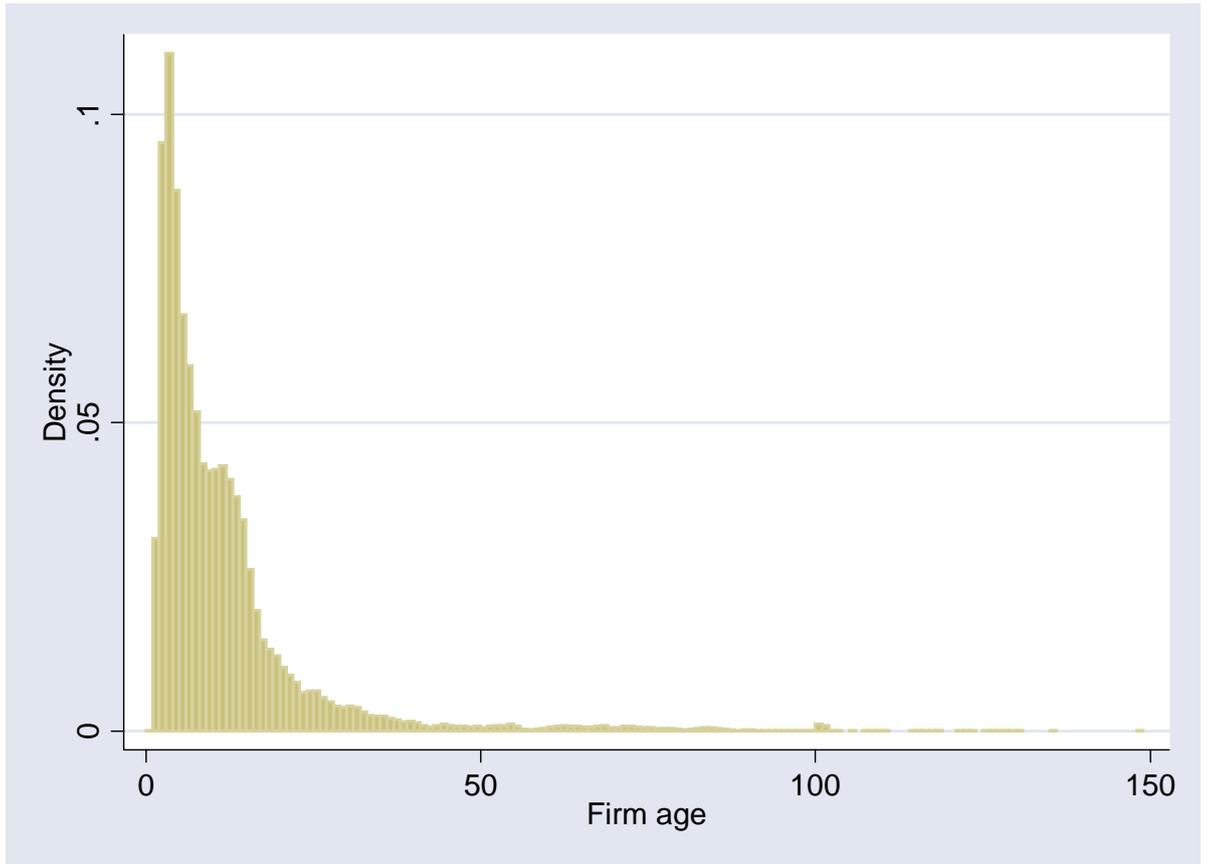
Figure 3.1: Distribution of firm age. Number of observations 60,362.
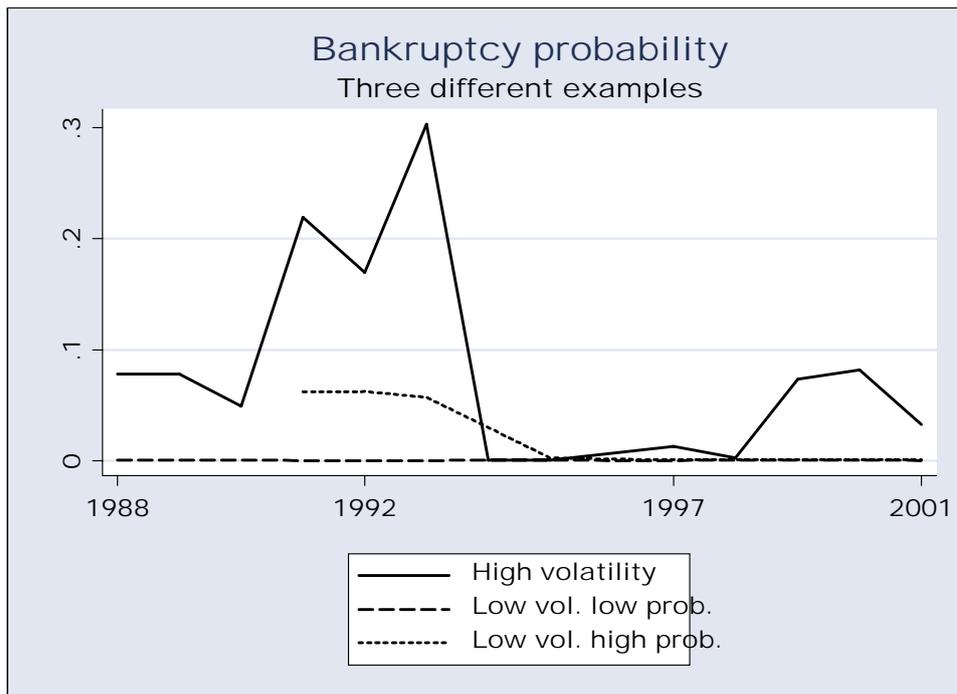
Figure 3.2: Volatility of bankruptcy probabilities.

informational advantage of the inside bank may expose the firms in this industry to considerable informational lock-in effects.[15]

## 3.3. The empirical model

Our theoretical model predicts that the interest rate markup is lower for younger firms, than for middle aged firms. For older, or more mature firms, it will again be lower. Furthermore, the model predicts that firms facing severe asymmetric information problems (more costly monitoring) experience a more pronounced markup cycle. In order to test these hypotheses we assign firms into three different age groups; young firms, middle aged firms, and old firms. Age groups are represented by dummies. Furthermore we allow the age dummies to interact with our measurement of the severity of asymmetric information.

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[15] An alternative measure of the inside bank's information advantage, could be the errors in the predictions of the bankruptcy probability model SEBRA. However, use of such a measure would implicitly assume that the inside bank has perfect information about the true bankruptcy probability of a borrower from the start of the lending relationship. We believe this is a too strong assumption, therefore we choose not to use this measure

19

As alluded to earlier, we want our empirical model to also enable a test of the two alternative predictions set out by Petersen and Rajan (1995) and Boot and Thakor (2000). In the paper by Petersen and Rajan the potential lock-in phenomenon of borrowers in relationship banking may stem from the exogenous competitiveness of the credit market, represented by a market concentration variable. In Boot and Thakor market concentration leads to more transactional lending and lower average interest rates.[16] Therefore we include a measure of credit market concentration and allow it to interact with firm age dummies in the same way as our measure of asymmetric information. Consequently, our empirical model can be used to test whether asymmetric information, credit market concentration, or both determine how the interest rate markup evolves over a firm's age.

We apply the following empirical model:

$$
\begin{aligned}
m_{i,t} \quad = \quad & \beta_0 + \beta_1 d_{YOUNG;i,t} + \beta_2 d_{OLD;i,t} + \beta_3 VL_{c,k} + \beta_4 VL_{c,k} \cdot d_{YOUNG;i,t} \qquad (3.3) \\
& + \beta_5 VL_{c,k} \cdot d_{OLD;i,t} + \beta_6 HI_{c,t} + \beta_7 HI_{c,t} \cdot d_{YOUNG;i,t} + \beta_8 HI_{c,t} \cdot d_{OLD;i,t} + \epsilon_{i,t} \quad ,
\end{aligned}
$$

where:

$d_{YOUNG;i,t}$ is a dummy taking value 1 if the firm is 10 years old or younger, 0 otherwise.[17]

$d_{OLD;i,t}$ is a dummy taking value 1 if the firm is older than 20 years, 0 otherwise.

$\Delta p_{i,t}$ is the change in bankruptcy probability of firm $i$ from year $t-1$ to year $t$.

$\sigma(\Delta p_i)$ is the standard deviation over time of $\Delta p_{i,t}$, i.e., a measure of the volatility in the bankruptcy probability of firm $i$. As discussed above, we use this volatility measure as a proxy for the asymmetric information problems related to lending to firm $i$. Higher volatility implies more severe asymmetric information problems.

$VL_{c,k}$ is the mean of $\sigma(\Delta p_i)$ for all firms in industry sector $k$ in county $c$. Essentially it captures the *volatility* of the bankruptcy probability of firms in the specific

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[16]Note that Boot and Thakor (2000) introduce a static model which does not have implication for the dynamic structure of interest rate markups.

[17]Cf. (Petersen and Rajan, 1995, p. 420) who also classify firms 10 years and younger as young firms.

industry and county. We regard it as a proxy for the severity of the *ex ante* asymmetric information problem in lending to a firm within this particular group of firms.[18]

$HI_{c,t}$ is the Herfindahl index for county $c$ in year $t$, measuring the market concentration of bank loans to all domestic non-financial business borrowers. Data for this variable is collected from the Norwegian banks statistics produced by Norges Bank (ORBOF).[19]

## 4. Results and discussion

The model (3.3) is estimated using OLS and White robust standard errors.[20] Results are presented in Table 4.1.

Table 4.1 shows that, ceteris paribus, young firms are charged a significantly lower interest rate markup than the group of middle aged firms (our reference group)[21]. So is also the case with the older firms, i.e., those older than 20 years of age. Thus, we find support for the life cycle pattern of interest rate markups over firms' age, as predicted by our theoretical model (Hypothesis I): All else equals, young firms are charged a lower interest rate markup compared to middle aged firms. As firms mature and get old (older than 20 years) they are again charged a lower interest

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[18]To calculate $VL_{c,k}$ we use observations spanning the whole period of the SEBRA-database, 1988 to 2001.

[19]In calculating the Herfindahl index we also include lending from mortgage companies to non-financial business borrowers. If a mortgage company is owned by a bank its loans are considered as part of the banks' loans. However, we do not include lending from finance companies, that mainly do factoring and leasing. Debts to these companies normally will not be included in the debt numbers we use to calculate the interest rates paid by borrowing firms.

[20]We note that the Herfindahl index $HI_{c,t}$ has constant values over all observations pertaining to one particular county in one particular year, that is, it is clustered. Clustering of RHS-variables tend to bias the estimated parameter standard errors downwards, (Bertrand, Duflo, and Mullainathan (2004)). To alleviate this potential problem we estimate the model using White robust standard errors also robust to clustering, by adjusting the variance-covariance matrix for those clusters using the *cluster* command in STATA.

[21]We define young firms as those 10 years old or younger. We also run the model with young firms being 5 years old or younger. However, the results obtained with that definition indicate that firms in the age group 5 to 10 years old still are subsidized by their bank.

Table 4.1: Results, dependent variable $m_{i,t}$

| Independent variable | Coefficient | Robust $t$-values |
|---|---|---|
| $\beta_0$ | 0.04163 | 9.88** |
| $d_{YOUNG;i,t}$ | $-0.00708$ | $-2.38$** |
| $d_{OLD;i,t}$ | $-0.01425$ | $-3.62$** |
| $VL_{c,k}$ | 0.06322 | 2.83** |
| $VL_{c,k} \cdot d_{YOUNG;i,t}$ | $-0.5314$ | $-15.65$** |
| $VL_{c,k} \cdot d_{OLD;i,t}$ | 0.2253 | 5.34** |
| | | |
| $HI_{c,t}$ | $-3.27 \cdot 10^{-6}$ | $-1.57$ |
| $HI_{c,t} \cdot d_{YOUNG;i,t}$ | $2.98 \cdot 10^{-6}$ | 1.81* |
| $HI_{c,t} \cdot d_{OLD;i,t}$ | $3.26 \cdot 10^{-6}$ | 1.51 |
| $F$-test for $HI_{c,t}$ terms | | 1.24 |
| # clusters | | 36 |
| # observations | 60362 | |
| $R^2$adj. | 0.0422 | |

The $t$-values reported are White-robust and adjusted for clustering of $HI_{c,t}$. * represents a 10 pct. statistical significance and ** 5 pct. significance

rate markup.[22]

The negative and significant value of the coefficient for $VL_{c,k} \cdot d_{YOUNG;i,t}$ indicates that for young firms the interest rate markup is decreasing in the informational advantage of the inside bank. The positive and significant values of the coefficients for $VL_{c,k}$ and for $VL_{c,k} \cdot d_{OLD;i,t}$ show that middle aged and old firms, respectively, both face higher interest rate markups the more severe the problems of asymmetric information for those firms are. These results support the hypothesis that the life cycle pattern of the interest rate markup is more pronounced for more opaque firms, i.e., firms which face stronger informational lock-in effects (Hypothesis II). Figure 4.1 illustrates how the markup for a typical firm changes as it moves through the three different age classes, young, middle aged, and old, keeping $VL_{c,k}$ and $HI_{c,t}$ constant. The vertical arrows indicate how the respective interest rate markups would shift as the opaqueness of the firm, $VL_{c,k}$, increases.

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[22] The way we have defined markup in this model it is not pure rent. It will also cover banks' operating costs. In addition there may be rent stemming from other deviations from perfect competition than those studied in this model. See for instance Kim, Kristiansen, and Vale (2005). These elements have been left out of our theoretical model. Hence the fact that our empirical model in (3.3) will yield positive interest rate markup even for young firms with very high severity of asymmetric information problem, can be consistent with the prediction of our theory model.
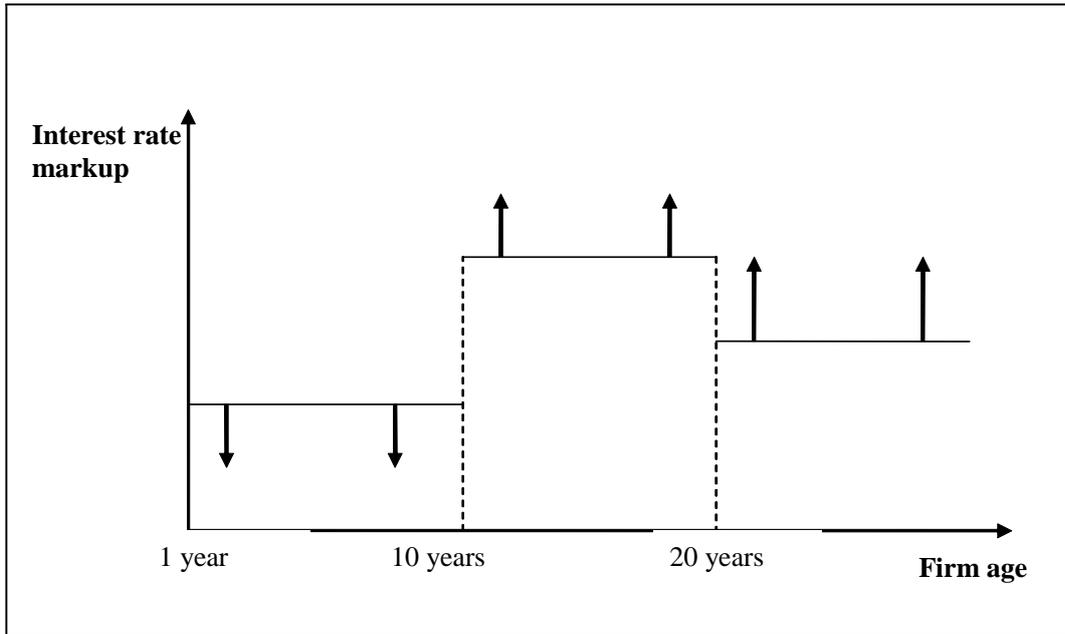
Figure 4.1: Interest rate markup for the three different age groups. The qualitative effects from increased volatility ($VL_{c,k}$) is illustrated by the vertical arrows.

The coefficient for $HI_{c,t}$ is negative but not statistically significant. Neither is the coefficient of $HI_{c,t} \cdot d_{OLD;i,t}$. The coefficient of $HI_{c,t} \cdot d_{YOUNG;i,t}$ is positive and significant at the 10 pct. level. Jointly the terms containing $HI_{c,t}$ are not significant, as demonstrated by the $F$-test. These results lead to a rejection of Hypothesis V that lower market concentration should lead to lower interest rate markup for old firms and higher markups for younger firms. I.e., we do not find support for the link between market concentration and interest rate markup charged to young firms as found in Petersen and Rajan (1995). Neither do the results give support to the competing Hypothesis VI: lower market concentration leads to higher interest rate markup.

Our results demonstrate that the informational advantage of the inside bank (measured as the volatility of firms' bankruptcy probability), and not market concentration, creates lock-in effects. Thus, to what extent banks subsidize very young firms in order to capture lock-in rents when firms are older, is determined by the informational advantage of the inside bank. A traditional measure of market competition, like the Herfindahl index, cannot explain the life-cycle of the interest rate

markup. We also run the model (3.3) replacing the Herfindahl index with the combined market share of the three largest banks in each market. The results were qualitatively the same as those reported in table 4.1.

The above empirical model (3.3) can not be used to test hypothesis III: banks will on average lend to riskier young firms if informational lock-in effects become stronger. To test this hypothesis we suggest the following procedure: First, we calculate the average bankruptcy probability for all observations of firms 10 years and younger within each industry sector $k$ in each county $c$, $\overline{p}_{YOUNG;c,k}$. For the same groups of observations we calculate the average interest rate markup, $\overline{m}_{YOUNG;c,k}$. We use these data to run the following simple regression

$$\overline{p}_{YOUNG;c,k} = \alpha_0 + \alpha_1 \overline{m}_{YOUNG;c,k} + \epsilon_{c,k} \tag{4.1}$$

Hypothesis III suggests a negative sign of $\alpha_1$, i.e., a more pronounced lock-in effect, measured as lower markup for young firms, implies that the average credit worthiness for young firms decreases. The estimated $\alpha_1$ coefficient is $-0.6856$, and the White robust $t$-value is $-34.70$.[23] This result indicates that increased lock-in due to asymmetric information improves the credit availability for young high-risk firms. Thus, hypothesis III is confirmed.

Our next step is to test Hypothesis IV: more opaque firms face longer lock-in periods. First, we calculate the predicted markup, $\widehat{m}$, for the three different age groups (cf. Figure 4.1), keeping $HI_{c,t}$ at its median value, and varying $VL_{c,k}$. If firms with high $VL_{c,k}$ face an interest rate markup that is increasing over firm age, while firms with a median or low $VL_{c,k}$ face a significant drop in their interest rate markup as they become old, we consider this as supporting Hypothesis IV: firms with severe asymmetric information problems face longer lock-in periods. In Table 4.2 we report the predicted markup, $\widehat{m}$, and its standard errors for the three different age groups for $VL_{c,k}$ at its median value and at its 95 pct. fractile value.

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[23]The number of observations is 4950 and the $R$-squared is 0.488.

Table 4.2: Predicted markups

Median value of $VL_{c,k}$

| Age group | Predicted markup | Std. error |
|---|---|---|
| Young firms | 0.0227 | 0.0008 |
| Middle aged firms | 0.0386 | 0.0015 |
| Old firms | 0.0344 | 0.0011 |

95 pct. fractile of $VL_{c,k}$

| Age group | Predicted markup | Std. error |
|---|---|---|
| Young firms | 0.0040 | 0.0017 |
| Middle aged firms | 0.0411 | 0.0019 |
| Old firms | 0.0459 | 0.0026 |

The predicted markups and their standard errors are reported as ratios. Young firms are firms 10 years or younger. Old firms are firms older than 20 years.

**Median value of VOL$_{c,k}$**
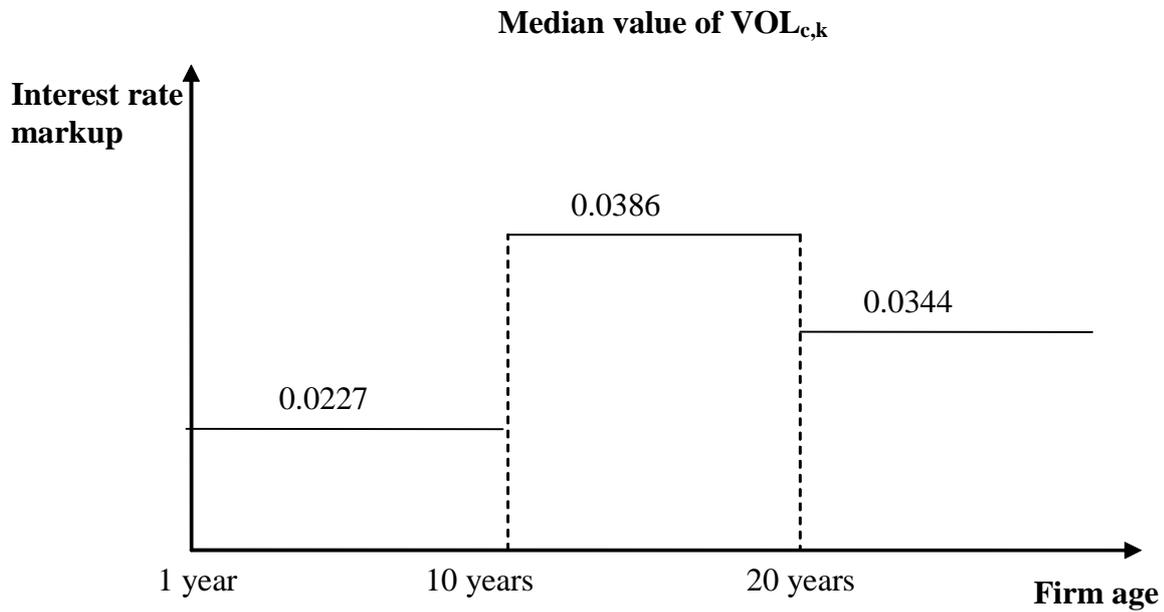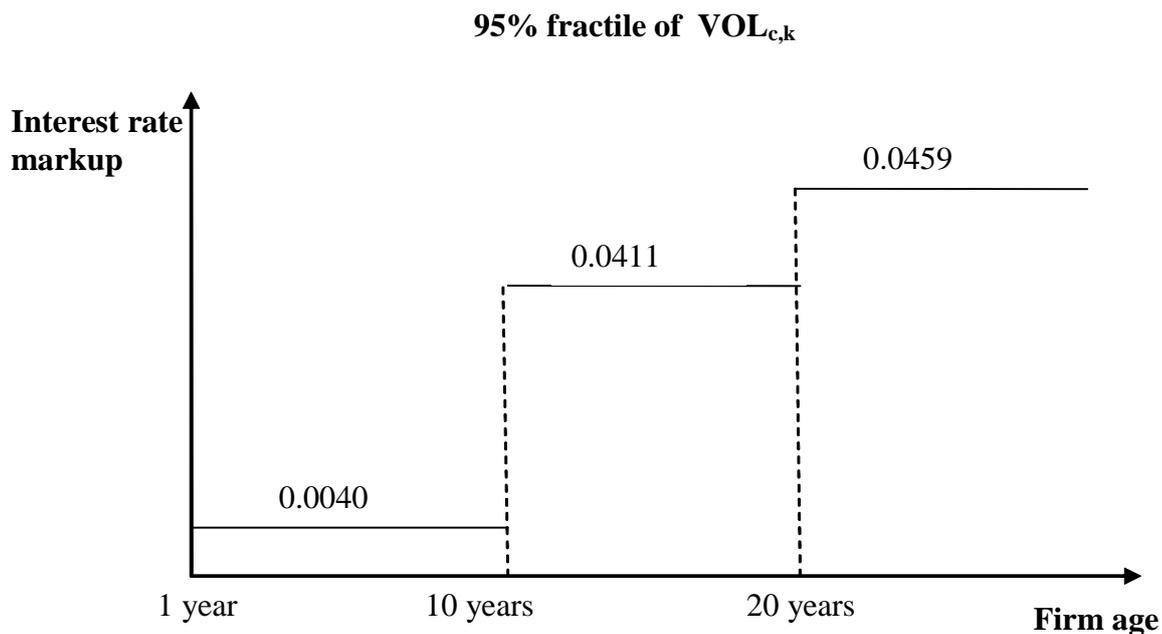


Figure 4.2:

Figure 4.3:

As shown in Table 4.2, for a firm with a median value of our opaqueness measure $VL_{c,k}$, the predicted markup is more than two standard errors lower for an old firm than for a middle aged firm. However, for a firm with a value of $VL_{c,k}$ corresponding to the 95 pct. fractile, the markup for an old firm is a little less than two standard errors higher than the markup for the middle aged firm. Hence, we have a 5 pct. significant *fall* in the markup for firms with median opaqueness going from middle to old age, and a 10 pct. significant *increase* in the markup for the firms with an opaqueness at the 95 pct. fractile going from middle to old age. See the illustrations in Figures 4.2 and 4.3. Thus, the lock-in period for very opaque firm lasts on, as opposed to less opaque firms where the markup reaches a maximum when firms are in the middle age. These results support our Hypothesis IV; more opaque firms have a longer lock-in period. However, with the setup of our model we are only able to detect empirically a longer lock-in period for firms with severe asymmetric information problems.

26

Since 63 per cent of our observations relate to young firms (firms 10 years old and younger), it could be argued that the volatility measure that proxies for the importance of soft information and potential for lock-in, may be dominated by higher bankruptcy volatility among the young firms. In order to check the robustness of our results with respect to this, we replaced $VL_{c,k}$ with a similar measure but now calculated only from firms older than 10 years, i.e., middle-aged and old firms. We rerun the model (3.3). The qualitative results remained the same as shown in this section, with just one exception.[24] See Appendix B.

## 5. Concluding remarks

We develop a theoretical model explaining the life cycle pattern of bank-borrower relationships. Our model predicts that, in order to attract new borrowers, banks offer loans with low or even negative interest rate markups to young firms. The inside bank – the bank at which a borrower initially has borrowed – obtains an information advantage which later on leads to lock-in effects and positive interest markups. As firms mature further they become more attractive borrowers for outside banks. That induces outside banks to make their own credit assessments in order to make competing loan offers. This additional monitoring results in a more dispersed firm-specific information and lower lock-in effects and, consequently, lower interest rate markups. Our theoretical model predicts that a stronger information advantage of the inside bank leads to a more pronounced life-cycle of interest rate markups and longer lock-in period. Using a large sample of Norwegian small firms and a novel measure of asymmetric information related to lending to each firm, we find empirical support for these hypotheses.

A large share of the existing literature has used market concentration in the loan market to explain interest rate markups. Our approach allows us to distinguish market-concentration effects from informational lock-in effects. In contrast to Petersen and Rajan (1995) which focus on market concentration variables, we find that our asymmetric information variables better explain the interest rate markup

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[24]The exception is $VL_{c,k}$ which is no longer statistically significant, although it is still positive. As alluded to in Appendix B, this may reflect the fact that the age at which firms become locked-in will vary between industries or even between firms, and thus will be difficult to determine accurately.

charged to young firms. We do not find any significant effect of market concentration on interest rate markups as predicted by Petersen and Rajan. Our study illustrates that banks market power is more closely related to the banks' information advantage – an Akerlof effect, than to its market share – a Herfindahl effect.

Furthermore, we find that stronger lock-in effects make banks more willing to lend to young high-risk firms. Thus, lock-in may contribute to the availability of bank credit to such firms.[25] This may have implications concerning financial stability. In a recession we would expect to see that banks experience more loan losses in market segments with significant lock-in effects than in other market segments.

The model we introduced contributes to the further understanding of the interaction and relationships established between banks and their borrowers. The specific methods by which a bank obtains soft information about a borrower during a relationship remains, however, to be further explored.

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[25]See Petersen and Rajan (1995) which in their empirical analysis examine how credit availability is associated with market concentration in the credit market.

# Appendix

## A. The bankruptcy probability model SEBRA

This appendix contains a brief description of the bankruptcy prediction model SEBRA. More detailed presentations are given in Eklund, Larsen, and Bernhardsen (2001) and in Bernhardsen (2001).

The SEBRA model is estimated based on individual limited liability firm accounting data. The model predicts the probability that a firm has its last year with a submitted account *and* within the next three years the firm is registered as bankrupt. All RHS variables, which are either firm or industry specific, are collected from the Register for Business Enterprises[26] where all Norwegian limited liability firms have to file their annual income and balance statements.[27] The data used to estimate SEBRA covers the years 1990 – 1996. Firms with total assets less than NOK 200,000 ($\approx$ 25,000 euros) are excluded. The total data set used consists of about 400,000 firm observations. The estimated model is a logit model in the predicted bankruptcy probability $\widehat{p}$ with the following RHS variables $x_i$:

- Earnings

  - earnings in per cent of total assets ($tkr$)

- Liquidity

  - liquid assets less short-term debt in per cent of operating revenues ($lik$)

  - unpaid indirect taxes in per cent of total assets ($ube$)

  - trade accounts payable in per cent of total assets ($lev$)

- Financial strength

  - equity in per cent of total assets ($eka$)

  - dummy for the event of book equity less than paid-in capital ($taptek$)

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[26]Foretaksregisteret i Brønnøysund

[27]Electronic versions of these acoounts have been supplied by Dun & Bradstreet.

- dummy for dividend payments the last accounting year ($div$)

- Industry variables

    - industry average for $eka$ ($meaneka$)

    - industry average for $lev$ ($meanlev$)

    - industry standard deviation for $tkr$ ($stdtkr$)

- Age

    - dummy variable for each of the first 8 years of the firm's age

- Size

    - total assets ($size$)

The structure of the model is as follow:

$$\widehat{p} \;=\; \frac{1}{1+e^{-\widehat{y}}} \quad \text{where}$$

$$\widehat{y} \;=\; \widehat{\beta}_0 + \widehat{\beta}_1 T_1(x_1) + \widehat{\beta}_2 T_2(x_2) + \ldots + \widehat{\beta}_k T_k(x_k) \quad \text{and}$$

$$T_i(x_i) \;=\; \begin{cases} \dfrac{1}{1+e^{-\left(\frac{x_i-\widehat{\alpha}_i}{\widehat{\delta}_i}\right)}} & \text{if } x_i \in \{eka, tkr, lik, lev, ube\} \\[2em] x_i & \text{if } x_i \notin \{eka, tkr, lik, lev, ube\} \end{cases}$$

The values of the estimated coefficients are reported in Eklund, Larsen, and Bernhardsen (2001). As expected $\widehat{p}$ is decreasing in $tkr$, $eka$, and $lik$, and it is increasing in $lev$ and $ube$. For the first 8 years of a firm's life the model predicts lower bankruptcy probability by each year, except going from the first to the second year. After 8 years age has by construction no effect on the bankruptcy probability. For the 5 non-linearly transformed variables the marginal effect on $\widehat{p}$ is non-linear in the sense that the absolute value of the marginal effect has a peak around a certain value of $x_i$.

Syversten (2004) compares the predictive power of the SEBRA model with that of Moody's KMV Private Firm model for Norway – hereafter referred to as KMV.[28] He uses "power curves" and their corresponding "accuracy ratios" to compare the bankruptcy predictions of SEBRA and the default probability predictions of KMV to actual bankruptcies for the four years 1998 – 2001. Syversten concludes that SEBRA's accuracy is as good as or somewhat better than the accuracy of KMV.

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[28] As KMV for Norway only covers about 3,500 firms and the SEBRA model covers more than 100,000 firms the comparison is based on a relatively small sample of the firms in the SEBRA model.

Table B.1: Results, dependent variable $m_{i,t}$, alterantive measure of $VL_{c,k}$

| Independent variable | Coefficient | Robust $t$-values |
|---|---|---|
| $\beta_0$ | 0.04319 | 10.45** |
| $d_{YOUNG;i,t}$ | $-0.01611$ | $-5.73$** |
| $d_{OLD;i,t}$ | $-0.01282$ | $-3.13$** |
| $VL_{c,k}$ | 0.01591 | 0.62 |
| $VL_{c,k} \cdot d_{YOUNG;i,t}$ | $-0.2543$ | $-6.18$** |
| $VL_{c,k} \cdot d_{OLD;i,t}$ | 0.1817 | 2.61** |
| | | |
| $HI_{c,t}$ | $-3.39 \cdot 10^{-6}$ | $-1.62$ |
| $HI_{c,t} \cdot d_{YOUNG;i,t}$ | $2.67 \cdot 10^{-6}$ | 1.60 |
| $HI_{c,t} \cdot d_{OLD;i,t}$ | $3.60 \cdot 10^{-6}$ | 1.66 |
| $F$-test for $HI_{c,t}$ terms | | 1.12 |
| # clusters | | 36 |
| # observations | 54886 | |
| $R^2$adj. | 0.0246 | |

The $t$-values reported are White-robust and adjusted for clustering of $HI_{c,t}$. * represents a 10 pct. statistical significance and ** 5 pct. significance

## B. Applying a different volatility measure

To check whether our results related to the estimation of (3.3) are driven by potentially higher volatility of the bankruptcy probability among young firms, we rerun (3.3) using a volatility measure excluding young firms. I.e., when calculating $VL_{c,k}$ we now only include firms 11 years old or older. Estimation results using this alternative volatility measure are shown in Table B.1.

As can be seen these results are qualitatively the same as those reported in Table 4.1, except that the coefficient of $VL_{c,k}$, although positive, is no longer statistically significant. The economic interpretation of this latter result is that increased volatility does no longer increase the lock-in effect of the middle-aged firms. However, this may simply reflect the fact that the age at which firms no longer are young, in the sense of becoming locked-in by their lenders will vary between industries or even between firms. Thus this age may be difficult to determine accurately from a

heterogeneous sample.[29]

The tests carried out for Hypothesis IV give the same qualitative results when using the alternative volatility measure as those reported in Table 4.2.

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[29]The robustness check performed in this appendix was also conducted defining young firms as those 12 years and younger. In that case the qualitative results were the same, but this time both the coefficient for $VL_{c,k}$ and the coefficient for $VL_{c,k} \cdot d_{OLD;i,t}$ were statistically significant at the 10 per cent level.

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