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DO BANKS TAKE EXCESSIVE RISKS WHEN INTEREST RATES ARE "TOO LOW FOR TOO LONG"?

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ABSTRACT

The financial woes that initiated the current economic slump have been traced to excessive bank risk-taking. What induced this behavior? One explanation is persistently low interest rates during the mid-2000s. In a model of a bank facing heterogeneous borrowers, we show that this hypothesis arises from rational profit maximizing behavior and does not reflect malfeasance or naiveté. We then exploit an extensive panel of matched Austrian banks and firms during 2000–2008, to show that the ECB policy of persistently low interest rates during 2003–2005, despite benign economic conditions, induced these banks to take on substantially riskier asset portfolios.

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1 Introduction

What made the worldwide financial system prior to its near collapse in 2008 so fragile and sensitive to a major crisis? One explanation is nicely summarized by Mervyn King:[2] In the wake of the dot-com bubble, extremely low interest rates throughout the entire western world have "[...] encouraged risk-taking on an extraordinary scale. Banks expanded their balance sheets [...] to satisfy the search for yield. [...] The build up of risk came to threaten the stability of the entire financial system." (King 2010, p. 4)

This paper explores one channel for such developments. In a model of a rational bank, that lends to a continuum of ex-ante indistinguishable heterogeneous firms, we characterize the relationship between the bank's cost of external funds and the ex-ante expected default risk in its loan portfolio. The model gives rise to the hypothesis that "too low" a cost of funds induces the bank to reduce its effort to screen out high risk borrowers and take on "excessive" amounts of default risk in its loan portfolio.

Based on the model's predictions, we develop a novel strategy to empirically test this hypothesis. We exploit an extensive panel of matched Austrian banks and firms for the period 2000-2008 to show that the ECB policy of a 2% refinancing rate throughout 2003-2005, combined with a substantial upswing in economic activity, induced Austrian banks to switch to significantly riskier business-loan portfolios.[3]

These findings imply potentially important consequences for the design and conduct of future monetary policy as well as financial regulation. For instance, Lorenzo Bini Smaghi, a former member of the Executive Board of the ECB, takes these concerns seriously and draws the following lesson for monetary policy makers: "[...] ensuring price stability is *not* sufficient for financial stability. [...] Protracted loose monetary conditions can foster excessive risk-taking and, consequentially, produce a build-up of financial imbalances" (Bini Smaghi 2011, original emphasis). It is thus not surprising that the IMF's Global Financial Stability Report from April 2013 devotes an entire chapter to discuss why "[...] central bank policies since the crisis carry risks to financial stability[.]" (IMF 2013, Chapter 3)

However, despite its political relevance, there are major challenges to a clean identification of such a mechanism. Our empirical strategy relies primarily on the fact that the

[2]For further illustrations of this hypothesis see for example Rajan (2010), Taylor (2007, 2009), Bernanke (2009), Obstfeld & Rogoff (2009), Ferguson & Schularick (2009), Obstfeld (2010), King (2010), Schularick (2010), Jordà et al. (2010), and references therein.

[3]The dataset is strictly confidential and was provided by the Oesterreichische Nationalbank (OeNB, Austrian Central Bank). Access to the anonymized individual data is granted by the OeNB's credit department on a case-by-case basis. Contact information can be found at www.oenb.at/.

ECB conducts monetary policy in order to stabilize the euro area as a whole, and does not exclusively react to economic developments in Austria. Naturally, since Austria is part of the "core" of European countries, there are many times during which euro area averages support the same policy actions that Austrian economic indicators would. In such a situation, ECB policy is endogenous despite the fact that policy is not directly geared toward exclusively stabilizing the Austrian economy. However, we show that there were several periods throughout 2000-2008 during which Austrian economic activity—as measured by inflation and output gaps—was substantially different from euro area averages. During such periods, we argue, the ECB's policy actions must have been perceived as exogenous from an Austrian point of view, provided that the policy decisions were in line with the mandate of stabilizing the euro area as a whole. We thus restrict our empirical analysis to precisely these situations and thereby ensure exogeneity of the ECB's monetary policy actions relative to the Austrian economy.

Our theory suggests a simple empirical test based on the comparison of such periods. During 2000-2008, the Austrian economy always improved (contracted) in absolute terms, whenever it switched from doing worse (better) to doing better (worse) than the euro area. In our model, such an aggregate economic improvement may be observed in response to two types of shocks: an aggregate productivity shock (loan demand shock), and a shock to investor wealth and thus available funds (loan supply shock). Both of these economic impacts yield the same prediction: If the bank's cost of funds is high enough, then either impact will cause a small and efficient increase in portfolio risk (if any). However, if the cost of funds is sufficiently low *and* remains unchanged after the shock, the model predicts a large and inefficient increase in portfolio default-risk.[4]

To design the optimal loan portfolio, the bank has to make three decisions: which projects to finance, how big a loan to advance to each borrower type, and whether to screen applicants. Ideally, the bank would like to tailor an individualized loan contract for each borrower and rank these contracts by their expected profits. If the bank does not have enough resources to fund every loan applicant the ability to discriminate is very valuable, as it allows the bank to reject the least profitable borrowers. Thus, the bank has a strong incentive to invest in screening its customers and most of either shock (productivity or investor wealth) will be absorbed through the intensive margin of portfolio adjustment: The bank expands more credit to the lowest risk types—which had already been serviced before—and only marginally extends the portfolio toward (new) higher risk types. However, if external funds are cheap enough so that the bank has the capacity

[4]The increase is inefficient relative to the full information first-best allocation

to fund almost every applicant, regardless of its quality, then the cost of obtaining the ability to discriminate may outweigh its benefits.[5] In such a situation, the impact of either shock will almost exclusively be absorbed through the extensive margin: The bank will stop screening, fund every applicant regardless of its risk type, and thereby drastically expand the portfolio toward (new) higher risk borrowers. This not only leads to an expansion in credit but also significantly increases the expected portfolio default-risk in an inefficient way, relative to the full information first-best allocation.

Thus, if banks' cost of external funds is sufficiently low and remains unchanged, we should expect an aggregate economic improvement to cause a sizable increase in expected default rates. On the other hand, when policy rates are sufficiently high and/or adjusted along with economic activity, such an aggregate economic improvement should cause no noticeable increase in expected default rates. The Austrian economy during 2000-2008 provides an excellent case study to evaluate this hypothesis.

The remainder of this paper is organized as follows: Section 2 starts with relating our work to the existing literature. We outline the model and its main predictions in Section 3. Section 4 describes our empirical strategy and the dataset, while Section 5 presents the main empirical results. Finally, we offer some concluding remarks in Section 6.[6]

2 Related Literature

The famous literature on the credit and bank-lending channels of monetary policy (Bernanke & Gertler 1995) emphasizes that lower short term interest rates cause credit expansions through an improvement in borrowers' collateral values. However, conditional on a borrower's creditworthiness, the policy rate has no effect on the lender's incentive to accept/reject a loan application in these models. We follow Borio & Zhu (2008) and investigate the possibility that, even if borrowers' creditworthiness is completely unaffected, the lenders' perceived attitude toward default-risk may change, if interest rates are sufficiently low.

This hypothesis has recently spurred a small but quickly growing literature that empirically studies the relationship between monetary policy and the risk-taking behavior of financial intermediaries (see for instance Jimenez et al. 2012, Altunbas et al. 2009, Mad-

[5]This logic is akin to Eden's (2012) result on the endogenous deterioration of the financial system in the western world as a consequence of financial integration.

[6]Appendices A through C present most of the formal derivations for our theory, the construction of the main empirical measure of portfolio-risk (based on logit models for banks' probability of default), as well as detailed regression tables. Appendices D through G report other supplementary materials.

daloni & Peydró 2011, Ioannidou et al. 2009, Delis & Kouretas 2011, De Nicoló et al. 2010). All of these articles are complementary to each other, in the sense that they find a reduced form relationship between short-term policy interest rates and some measure of "risk" for the financial sector as a whole, particular types of financial institutions, or individual borrowers. The distinguishing factors between the individual contributions are mainly the data source, the employed measure of "risk", and the particular identification strategy.

Like Altunbas et al. (2009), De Nicoló et al. (2010), as well as Delis & Kouretas (2011), we focus on the effect of banks' cost of external funds on the risk composition of its loan portfolio. These studies utilize an array of publicly available measures of banks' portfolio-risk—like expected default frequencies or risk-weighted assets—and postulate that changes in these measures capture changes in banks' risk-taking behavior. In contrast, we construct the expected default rate within each bank's loan-portfolio directly from detailed balance sheets and loan portfolios. This allows us to construct a measure of risk that is consistent with our theoretical model and thus allows us to directly derive and interpret a testable hypothesis.

Furthermore, we focus on the effect of policy interest rates that are low and unchanged for an extended period, as opposed to short term adjustments to the policy rate. Maddaloni & Peydró's (2011) work is most closely related in this respect. They find that the number of quarters, that short term interest rates stay below the prediction of a Taylor (1993) rule, significantly decrease banks' lending standards. While their hypothesis and identification strategy are closely related, they are distinct from ours.

Most importantly, we treat the period between June 6, 2003 through December 6, 2005, during which the ECB kept its refinancing rate constant at an unprecedented low of 2 percent, as a single "event". We then utilize our model's predictions to derive a hypothesis for the effects of this event based on time series variation in economic activity within this period. The basic idea behind our empirical strategy is akin to the "differences in differences" estimator (Card & Krueger 1994). The main modification in our paper is that, traditionally, a "control group" is defined according to some cross-sectional criterion (like geography in Card & Krueger (1994)) while we select it along the time dimension.

There has been very little theoretic work on the precise mechanisms underlying a potential relation between short term interest rates and bank risk-taking. Among the few exceptions are Farhi & Tirole (2012) as well as Diamond & Rajan (2012). Both papers show that anticipated cheap liquidity—for instance, through announced monetary policy—may serve as insurance against future liquidity risk and thus spur excessive investment into illiquid long term assets. Like Agur & Demertzis (2010) these papers focus mainly on the question of whether incorporating the goal of financial stability directly into central banks' objectives could improve equilibrium welfare.

The mechanism envisioned in this paper is complementary and most closely related to recent work by Laeven et al. (2010) and Dell'Ariccia & Marquez (2006). The key result in these studies is that a bank's screening effort may depend on the cost of external funds, an effect that arises even in the absence of maturity mismatch. Like in their models, we incorporate the bank's decision of whether to screen out bad risks in the spirit of Holmstrom & Tirole (1997), Cerasi & Daltung (2000), and Carletti (2004). This model element seems especially important in light of the work by Maddaloni & Peydró (2011), who find that lower short term interest rates tend to soften banks' lending standards.

The information structure in our model follows setups in the spirit of de Meza & Webb (1987) as well as Besanko & Thakor (1987). One crucial difference between these two models is that one assumes fixed amounts of investments, while the other treats investment as a continuous choice. We combine both features to accommodate the fact that observed loan portfolios show significant variation in both loan size and the range of risk types financed.

Finally, the main theoretic result of an endogenous reduction in the efficiency of the investment allocation, due to a change in the bank's cost of external finance, follows the same logic as Eden's (2012) findings on the effects of financial integration. She shows that global financial integration, which is perceived as a reduction in the cost of external finance in the developed world, may lead to an endogenous deterioration of the financial system in advanced economies. While the details of her model differ significantly from our approach, the underlying mechanism is the same.

3 The Model

To guide our empirical analysis we build a model that serves two purposes: First, we seek to characterize the relationship between banks' cost of external funds and the default-risk composition of its business-loan portfolio. Second, we analyze the effect of an aggregate economic upswing on the bank's portfolio risk in two alternative scenarios: one in which the cost of external finance is high and/or increases along with the economic improvement, and one in which it is low and remains unchanged.

3.1 Firms

We consider a continuum of firms (of mass 1), each of which is endowed with an identical production technology, $F(K) \geq 0$, with $F(0) = 0$, $F'(K) > 0$, $F''(K) < 0$, $F'''(K) > 0$ and $\lim_{K \to 0} F'(K) = \infty$. In order to produce, firms not only have to install working capital $K > 0$ but also need to incur a sunk start-up cost, $C^F > 0$.

Each firm is subject to idiosyncratic uncertainty about the success of production. The firm delivers $F(K)$ units of output with probability $(1 - \lambda) \in [0, 1]$, while no output is being produced with probability λ. Thus, a firm has to default on its loan with probability λ. Each firm draws its idiosyncratic probability of default, λ, from a distribution $G(\lambda)$, with density $g(\lambda)$.[7] To keep the model simple, this is the only degree of heterogeneity among firms. In our empirical analysis, we will estimate each firm's probability of default based on observed characteristics, including factors like capitalization, liquidity, profitability, etc.[8] Thus, we think of λ as a reduced form index of measured firm quality, taking into account all observable information about the firm. Throughout the rest of the paper we index individual firms by their idiosyncratic probability of default, λ. We further assume that firms have to finance both the start-up cost and the working capital with a bank loan of size, $L(\lambda) = C^F + K(\lambda)$. Again, this assumption is a reduced form way to model the fact that the firm's internal liquidity, as well as external finance other than bank-loans, is already incorporated in λ and we focus on the bank-loan portion of finance here. Furthermore, we have our sample of Austrian firms in mind, whose predominant form of finance are bank-loans.[9]

Finally, we assume that firms are protected by limited liability (in the extreme form of *no* liability). We make this assumption to simplify the analysis and to reflect the observation that about 70% of the firms in our sample are classified as "limited liability companies" ("Gesellschaft mit beschränkter Haftung", or GmbH).[10]

[7] In principle, a firm's probability of default is likely related to monetary policy as in models of the classic bank-lending/credit channel (e.g. Bernanke & Gertler 1995). However, the assumption of an exogenous λ is not material for our exercise. It is our goal to characterize the effect of policy interest rates on the *composition* of risk within a bank. Lower interest rates improve *every* firm's net worth and thereby lower its probability of default. Thus, if banks maintain a fixed cutoff for "acceptable default risk", say $\hat{\lambda}$, there will be more lending since more firms may now be deemed creditworthy. However, the average expected default risk within a bank's portfolio (if at all) *decreases* in response to such an expansion of lending. The mechanism envisioned in our paper *increases* the average expected risk within the banks portfolio and thus works in the opposite direction. Therefore, any net-positive effect on average expected default risk cannot be caused by the classic credit channel and our eventual testable hypothesis does not hinge on this assumption.

[8] See Appendix B.

[9] See Table 1. Only about 11% of the firms in our sample are classified as "equity firms" (Aktiengesellschaft) and about 50% of firms' liabilities are bank liabilities.

[10] See Table 1.

Since firms are unable to produce without bank financing, each firm will apply for a loan with the bank.

3.2 The Bank

Again, with our sample in mind, we model a representative monopoly bank. This simplifying assumption draws on the fact that the majority of Austrian banks is very small and operates predominantly locally.[11]

Since we will control for bank capitalization in our empirical analysis, and thereby essentially compare banks of equal capitalization, we assume that the bank has no capital. Thus, in order to make loans to businesses, the bank needs to collect deposits and pay an exogenously given deposit rate $R^d > 1$ on these external funds.[12]

The bank knows the cross sectional distribution of default risk, $G(\lambda)$, but cannot ex-ante distinguish between particular loan applicants. However, it has the option to incur a cost $C^S > 0$ to screen applicants and obtain perfect information about each applicant's probability of default, λ.[13] One interpretation of the cost C^S is the amount of fees paid to a credit rating agency, which provides the bank with a menu of ratings. Alternatively, C^S may simply be thought of as the cost of hiring analysts who screen applicants in-house. To keep the analysis as simple as possible we assume that any other form of screening mechanism (e.g. requesting collateral or other loan covenants) is just as costly as directly obtaining perfect information.

As a consequence, the bank's optimization problem consists of two stages: First, the bank decides whether to acquire perfect information at cost C^S. In the second stage, it decides on the optimal menu of loan contracts to post. We solve this optimization problem via backward induction, starting with the second stage pricing decision, taking the first stage choice as given. Since our main goal is to motivate our empirical test, we leave

[11]This assertion is supported by van Leuvensteijn et al. (2013), who recently found that competition within the Austrian banking sector is very low, especially compared Germany and Italy. In fact, based on a new competition measure by Boone (2008), they cannot detect significant degrees of competition in the Austrian banking sector for most of the years between 1994-2004. Moreover, in the few years for which they do detect significant degrees of competition, their point estimates are very low relative to almost all other countries in their study. We presume that most of the effect is probably driven by the few very large Austrian banks, who face substatntial international competition.

[12]In making this assumption we essentially postulate that business only consider the local bank as their lender while depositors are more comfortable with depositing in banks that are not necessarily close to their location. Thus, the bank has no significant influence on the going deposit rate.

[13]To make the illustration as clear as possible we allow the bank to purchase perfect information. We acknowledge that, in reality, ratings are by no means perfect, but this assumption simplifies the analysis significantly. An interesting extension would be the case of imperfect signals about the true quality of firms. We leave this extension for future research.

most of the detailed derivations and proofs for Appendix A and focus on an intuitive exposition of the results in the main text.

3.3 The Optimal Loan Portfolio

If the bank chooses to incur the screening cost C^S it is in the position to perfectly discriminate between loan applicants. It will thus post a menu of loan contracts $\{L(\lambda), R(\lambda)\}_{\lambda\in\Lambda}$, where $\Lambda \subseteq [0,1]$ is the set of firms who eventually receive funding, that solves the following optimization problem:

$$\pi^S = \max_{R(\lambda),L(\lambda),\Lambda} \left\{ \int_\Lambda L(\lambda) \left[(1-\lambda)R(\lambda) - R^d\right] dG(\lambda) \right\} - C^S \tag{1}$$

such that

$$(1-\lambda)\left[F(K(\lambda)) - L(\lambda)\cdot R(\lambda)\right] \geq 0 \tag{2}$$

$$K(\lambda) + C^F = L(\lambda), \tag{3}$$

where $R(\lambda)$ is the individualized gross interest rate charged on a bank loan, $L(\lambda)$, advanced to firm $\lambda \in \Lambda$. Equation (2) states that firms need to earn at least zero profits in order to accept the loan contract, and (3) defines the loan size for each firm.[14]

Since it is always optimal for the monopoly bank to extract as much surplus as possible, constraint (2) will always be binding. This allows us to write the bank's profit expected from a loan advanced to firm λ as

$$\pi^S(\lambda) = (1-\lambda)F(K(\lambda)) - R^d \cdot \left[K(\lambda) + C^F\right]. \tag{4}$$

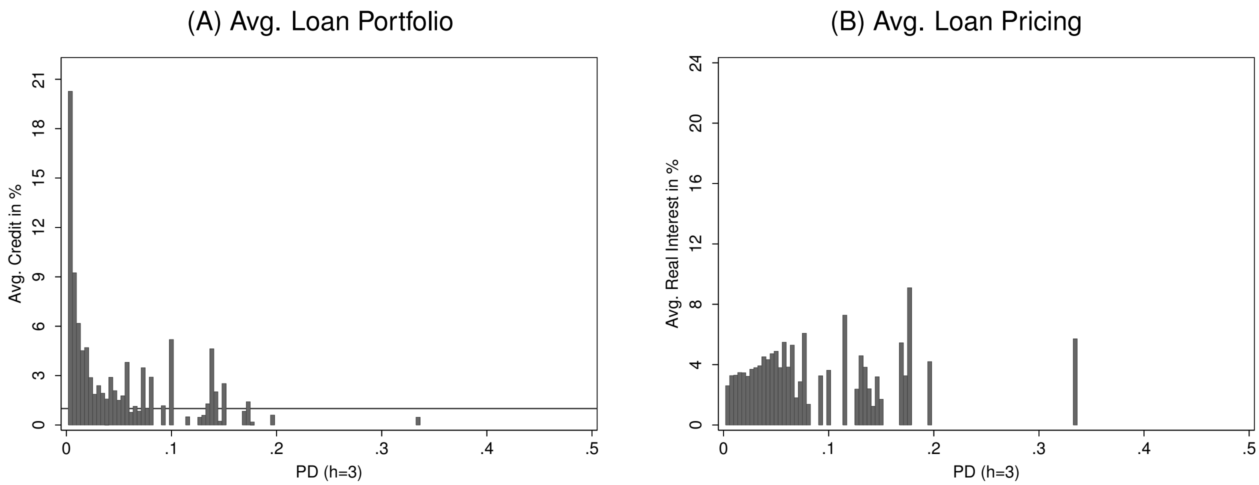
Since $F(K)$ is monotonically increasing and strictly concave $\pi^S(\lambda)$ is strictly concave in K. Thus, the optimal loan contract tailored for firm λ needs to satisfy the first order condition

$$(1-\lambda)F'(K(\lambda)) = R^d \tag{5}$$

which directly implies that $K(\lambda)$ is decreasing in λ. Condition (5) states that the bank's expected marginal revenue from increasing $K(\lambda)$—and thus the loan $L(\lambda)$—must equal the marginal cost of the extra deposits necessary for that loan increase. This condition to-

[14]Note that it is not immediately obvious why Λ is necessarily a connected set and that the integral in optimization problem (1) is well defined. This is verified in Corollary 1, the validity of which is independent of the existence of the integral in optimization problem (1).

Figure 1: Loan Portfolio and Pricing (Austria 2000–2003)



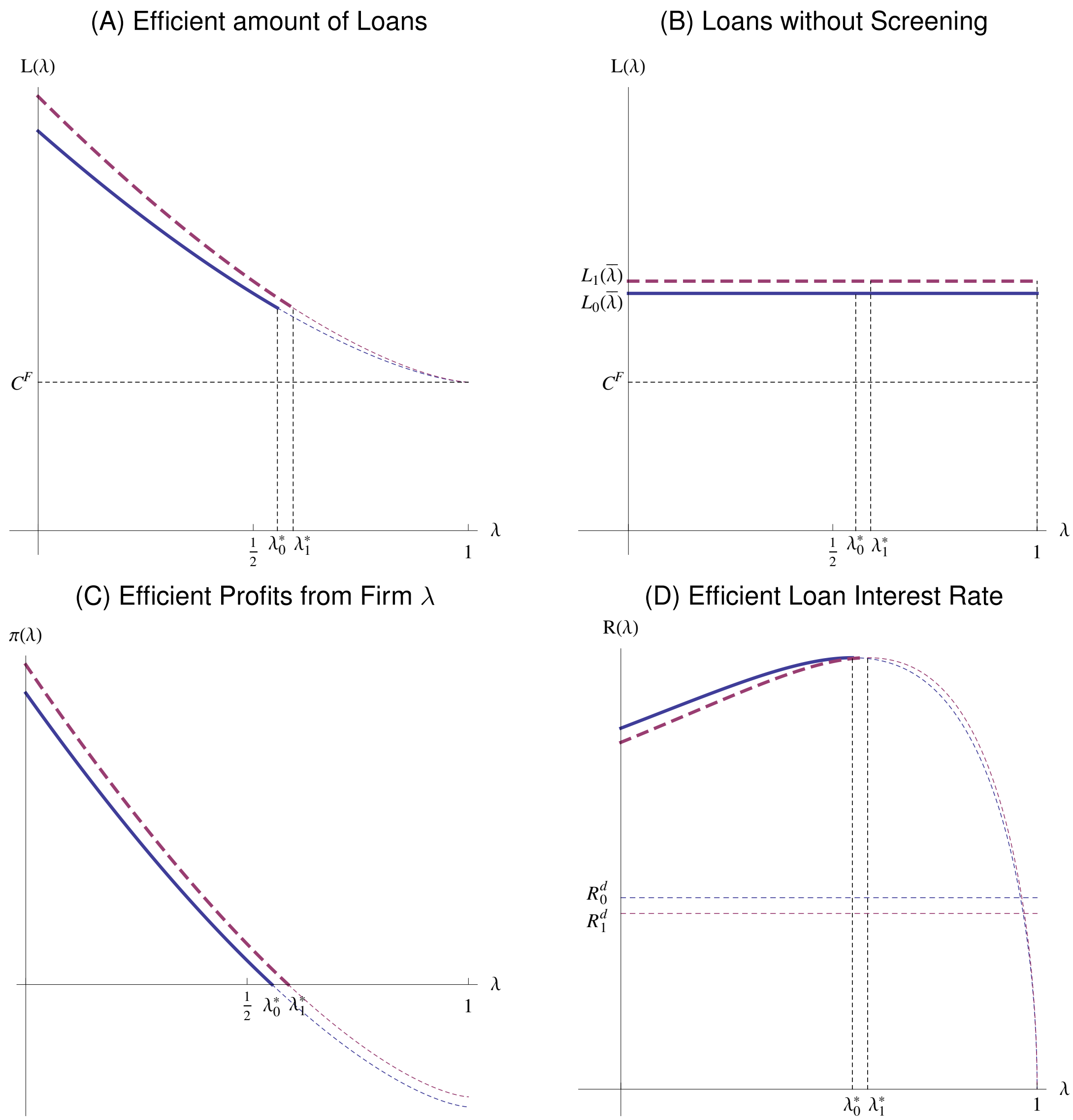
Notes: The graphs are constructed from the dataset described in Section 4.2. The probabilities of default (PD) are based on logit estimates described in Appendix B for a bankruptcy horizon of $h = 3$ years. Firms are grouped by PD in 100 equally spaced bins. Real interest rates are constructed from firms average expenses on interest as described in Appendix B. The graphs are based on monthly observations of firm-bank level stocks of lending and the exact cutoff dates are 2000/1 and 2003/6. This time horizon corresponds to the period before the ECB lowered its main refinancing rate to an annual rate of 2%.

gether with equation (2) implies that the profits extracted from the optimal loan contract for firm λ are strictly decreasing in the probability of default. Thus, with perfect information, it is optimal for the bank to advance the largest loans and also extract the largest profit from the safest businesses. This is because the marginal cost of lending one unit of working capital, R^d, is constant. As the probability of default, λ, increases the bank needs to offset the extra default risk through reducing the amount of working capital granted.

Figure 1 illustrates that this feature is consistent with the average loan portfolio of Austrian banks in our sample. This finding is also in line with existing empirical studies, reporting that the largest firms in an economy display the smallest volatility in output (Gabaix 2009).

Since deposits are inelastically supplied at the deposit rate R^d the bank will find it optimal to advance loans to any firm from which it expects at least zero profits, i.e. $\pi^S(\lambda) \geq 0$. In particular, as $\pi^S(\lambda)$ is monotonically decreasing in λ, the bank will start advancing loans to the risk-less firms first and then gradually expand the portfolio toward higher risk borrowers. It will stop granting loans if either every applicant has been served, i.e. $\lambda = 1$, or the marginal borrower, λ^*, becomes unprofitable, i.e. $\pi^S(\lambda^*) = 0$. Since the total loan granted to each borrower also includes the firm's fixed cost, there always is a marginal borrower $\lambda^* < 1$ as long as $C^F > 0$. Thus, the presence of a fixed start-up cost

Figure 2: Optimal Loan Contracts



Notes: The graphs were constructed assuming that $F(K) = K^{1/3}$, $C^F = 0.1$, $S^C = 0.044$, and $G(\lambda)$ is uniform. The thick solid lines represent a situation with a deposit rate of $R^d = \tilde{R}^d = 1.0411$ while the thick dashed lines depict the optimal loan portfolio for a slightly lower deposit rate.

for firms introduces an extensive margin to the portfolio adjustment.

Furthermore, a lower cost of external funds, R^d, allows the bank to profitably expand the loan portfolio at the high-risk end. This implies that a decrease in the cost of funds not only implies an increase in the amount lent to borrower types who have previously been serviced, but it also allows the bank to service new higher risk borrowers. Consequently, under prefect information, a reduction in the cost of funds allows the bank to expand its loan portfolio both along the intensive as well as the extensive margin. Again, this adjustment along the extensive margin contributes to the increase in aggregate lending.

Panels (A), (C), and (D) of Figure 2 graphically illustrate these findings. The thick lines in each of the three panels plot the functions $L(\lambda)$, $\pi^S(\lambda)$, and $R(\lambda)$ for two alternative deposit rates $R_0^d > R_1^d > 1$, where the solid line corresponds to R_0^d and the dashed line represents the case in which deposit rates are slightly lower, at R_1^d.

Finally, panel (D) illustrates another salient feature of observed loan contracts. In an optimal contract under perfect information, banks charge a risk premium over the deposit rate that is increasing in λ on the set of approved applicants Λ^*. The logit estimates reported in Appendix C as well as panel (B) of Figure 1 empirically support this equilibrium feature for Austrian business lending throughout the period 2000-2008.

If the bank does not incur the screening cost C^S it can only offer a single pooling contract (R, L) that is identical for every customer.[15] In this case, the optimization problem collapses to maximizing the profits generated from a loan to the average borrower in the population, $\bar{\lambda}$, and is defined by $\pi^{NS} = \pi^S(\bar{\lambda})$ using equation (4). Consequently, the optimal contract without screening is simply the loan contract designed for the average borrower under perfect information, i.e. $K = K(\bar{\lambda})$ and $R = R(\bar{\lambda})$, where $K(\cdot)$ and $R(\cdot)$ are the solutions to the optimization problem with screening, stated in (1).[16]

Panel (B) of Figure 2 illustrates the no-screening counterpart of panel (A). Notice that a reduction in the cost of funds will now induce a completely symmetric expansion in credit across all customers. Thus, without screening the intensive margin of adjustment remains but is unambiguously symmetric. Finally, since every customer is always serviced, there is no extensive margin of adjustment in response to a change in the cost of funds.

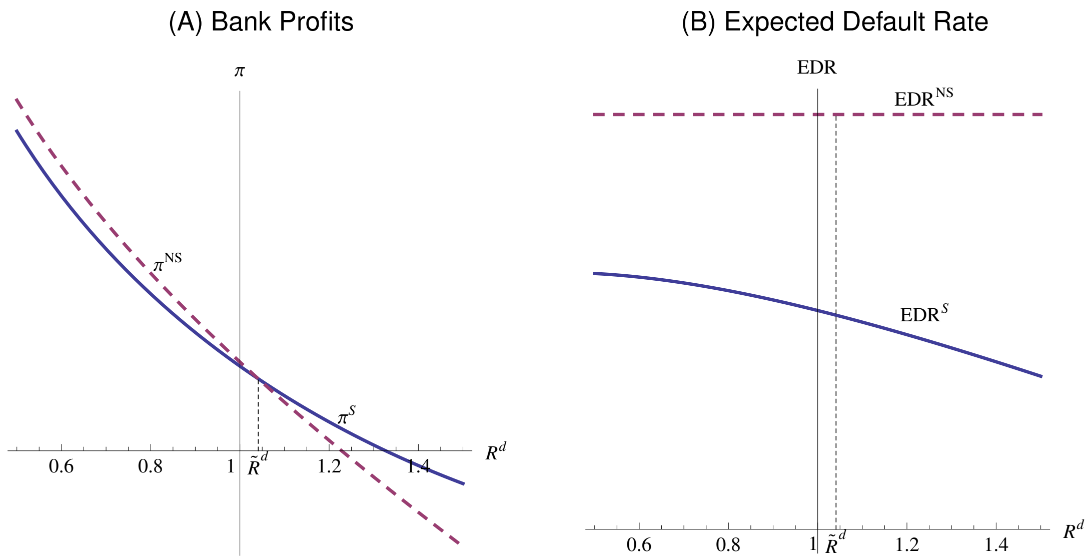
3.4 The Optimal Screening Strategy

In order to decide whether to screen loan applicants, the bank simply compares the expected aggregate profits from either second stage scenario. If aggregate profits under perfect information, and after paying the fixed screening cost, are at least as large as profits from the single pooling contract, the bank will choose to invest in the screening technology.

[15]Since firms own no capital, collateral cannot be used as a sorting mechanism and we assume that constructing alternative separating equilibria (through other loan covenants) is just as costly as paying the fixed cost C^S.

[16]See appendix A for formal derivations.

Figure 3: Bank Profits and Portfolio Risk



Notes: The graphs were constructed assuming that $F(K) = K^{1/3}$, $C^F = 0.1$, $S^C = 0.044$, and $G(\lambda)$ is uniform. These parameter values imply a threshold of $\tilde{R}^d = 1.0411$.

The cost of external funds plays an important role in this decision, as it determines the effective amount of liquidity available to the bank. If the deposit rate is very high, the bank is limited in its lending volume. Thus, the value of being able to separate customers is very high. Conversely, if the cost of funds is very low, then the bank is flush with liquidity and can serve a large portion of customers despite the screening cost. However, as the bank gets closer to servicing the entire market, the relative value of acquiring information about borrower quality diminishes. Thus, there may be a point at which the bank would rather choose to make loans to everybody at "average" loan terms and thereby avoid paying the screening cost. Panel (A) of Figure 3 depicts the profit functions under screening and no-screening, and illustrates a situation in which there is a critical deposit rate, $\tilde{R}^d > 1$, below which screening becomes unprofitable.

3.5 The Relation Between the Cost of Funds and Banks' Portfolio Risk

The main purpose of our model is a characterization of the relation between the cost of external funds and the bank's loan-portfolio risk. We measure the bank's aggregate default-risk by the expected default rate within the bank's portfolio, defined as

$$EDR = \frac{\int_0^{\lambda^*} \lambda L(\lambda) dG(\lambda)}{\int_0^{\lambda^*} L(\lambda) dG(\lambda)}. \tag{6}$$

If the bank chooses to screen its customers, this measure of default-risk will always be below that within a pooling contract. Panel (B) of Figure 3 illustrates this property graphically. Thus, the model implies that, if the deposit rate falls below the critical value $\tilde{R}^d$, then banks stop screening customers and significantly increase the aggregate default risk within their loan portfolios.

3.6 A Simple Testable Hypothesis

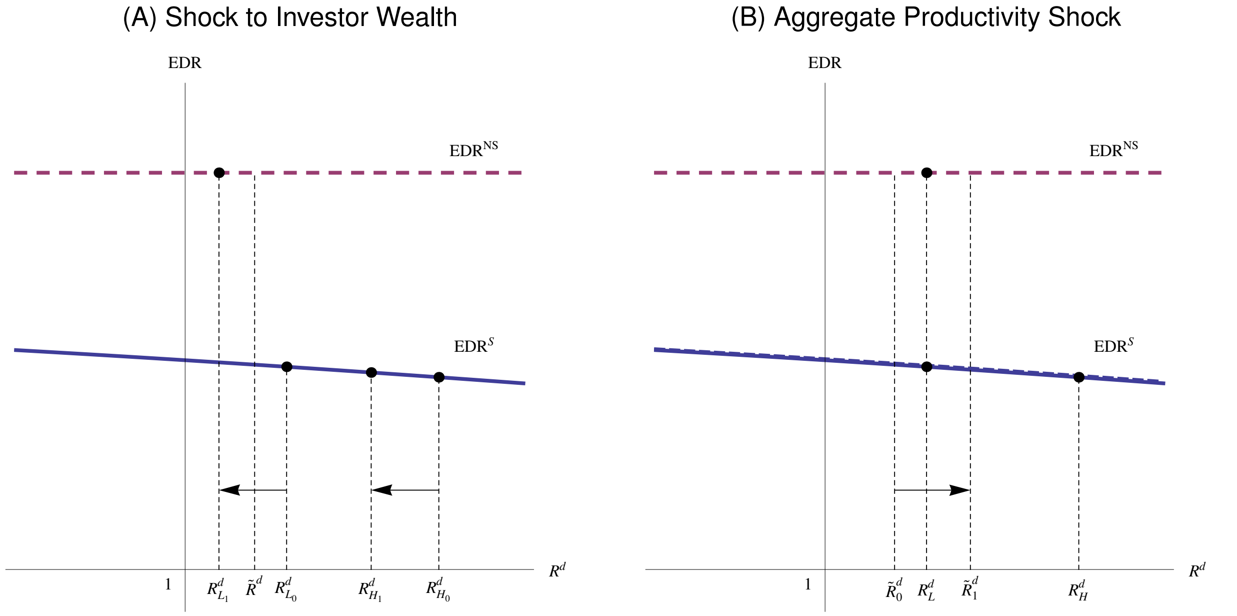
In this section, we illustrate how either a supply or a demand shock may cause banks to switch from the separating to to the pooling equilibrium, if monetary policy keeps interest rates sufficiently low and unchanged.

Imagine that the effective cost of funds for banks is comprised of the central bank's policy rate, R^{FF}, plus a premium charged by depositors, $P(W) \geq 0$, which depends negatively on the depositors' wealth, $W > 0$. Thus, if the central bank keeps its policy rate fixed, but depositors experience a significant wealth shock—like an unexpected increase in their housing wealth—, then this will lead to a reduction in banks' effective cost of funds $R^d = R^{FF} + P(W)$. Consequently, if the initial level of R^d is sufficiently low and close to $\tilde{R}^d$, then such a shock to depositors' wealth may induce banks to significantly—and ex-post inefficiently—increase their portfolio risk. Panel (A) of Figure 4 illustrates this thought experiment. If the initial deposit rate is $R^d_{H_0}$ and a shock to investor wealth reduces the effective deposit rate to $R^d_{H_1}$, there is only a marginal increase in the expected default rate. If, on the other hand, the initial deposit rate is $R^d_{L_0} > \tilde{R}^d$ and the investor wealth shock reduces it to $R^d_{L_1} < \tilde{R}^d$, then this leads to a large and inefficient increase in the expected default rate.

A similar effect may arise from an aggregate productivity shock. Imagine that the production function takes the form $F(K) = Af(K)$. Then, an increase in A can be thought of as an aggregate productivity shock. Like a reduction in R^d, such a shock slightly increases the expected default rate if banks are screening. This effect is illustrated in panel (B) of Figure 4. The increase in A shifts the curve representing EDR^S marginally upward. The new EDR^S schedule is represented as the dashed line that is virtually on top of the initial EDR^S curve. Thus, at a deposit rate R^d_H there is only a very small increase in the expected default rate in response to an increase in A.

However, such a shock will also increase the cutoff level for the deposit rate $\tilde{R}^d$. This

Figure 4: Differential Effects of Advantageous Aggregate Shocks



Notes: The graphs were constructed assuming that $F(K) = K^{1/3}$, $C^F = 0.1$, $S^C = 0.044$, and $G(\lambda)$ is uniform. These parameter values imply a threshold of $\tilde{R}^d = 1.0411$.

is because an increase in A simply increases the difference in expected revenue (and thus profit) between screening and a pooling contract.[17] This implies that an aggregate productivity shock will result in an effect that is qualitatively equivalent to that of an investor wealth shock. Panel (B) of Figure 4 illustrates this effect. If the deposit rate R_L^d is sufficiently close to $\tilde{R}_0^d$, then the increase in the cutoff deposit rate, to $\tilde{R}_1^d > R_L^d$, leads to a significant and inefficient increase in the expected default rate.

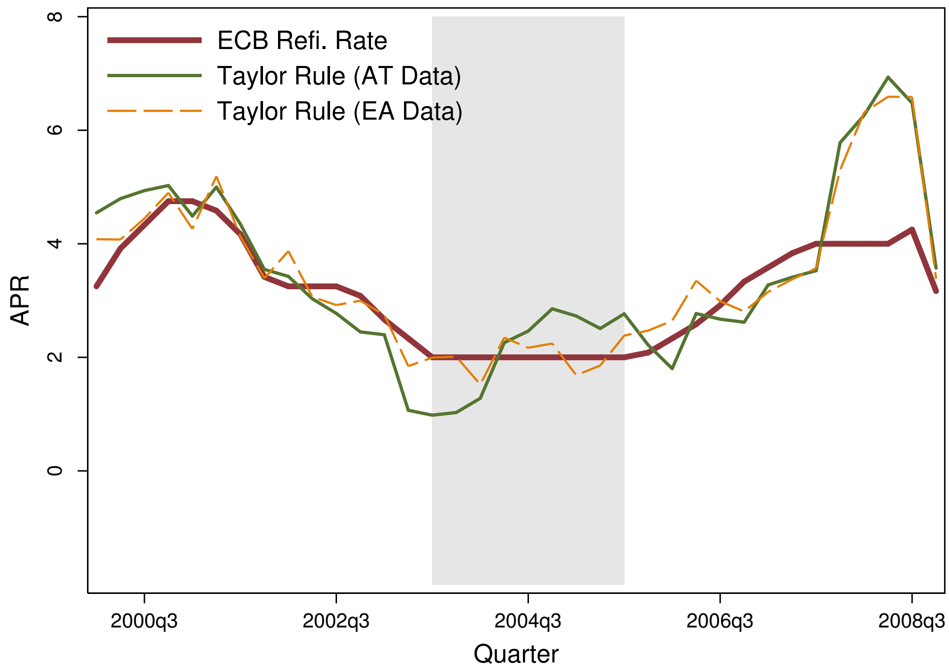
Thus, the model gives rise to the following testable hypothesis: An economic improvement—be it a supply or a demand shock—may cause a significant increase in expected default rates in banks' loan portfolios, if the cost of funds is sufficiently low *and* remains unchanged despite the economic improvement.

4 An Empirical Test

Based on the hypothesis posed in the previous section, we develop an empirical strategy to assess whether the ECB policy stance between June 6, 2003 and December 6, 2005, during which the refinancing rate remained at a then unprecedented low of 2% p.a., sig-

[17]This is captured by the combination of the expressions for the extensive and intensive margin in equation (31).

Figure 5: Economic Activity in Austria



Notes: The figure displays the gap between a Taylor Rule for Austria (AT) and the Euro Area (EA), as specified in equation (8). The thick solid line represents the ECB's main refinancing rate.

nificantly increased the amount of risk allowed in Austrian banks' business-loan portfolios.

The basic idea is to compare the reaction of the average banks' allowed default-risk in response to a significant improvement in aggregate economic activity during two alternative monetary environments: One in which the refinancing rate is being adjusted along with economic activity (2000q1 – 2003q2 and 2005q4 – 2008q3 in our sample) and one in which interest rates remain low and unchanged despite the significant change in economic activity (2003q3 – 2005q3 in our sample).

Figure 5 illustrates economic activity in Austria between 2000 and 2008. Our baseline measure of economic activity is a weighted average of inflation and output gaps, which we construct similarly to Taylor (1993).[18] Thus, throughout the remainder of this article we will refer to this measure of economic activity as a "Taylor rule". Figure 5 clearly highlights that Austria experienced a significant economic downturn throughout 2000q1

[18] See Appendix G for details on the construction of the Taylor rule.

– 2003q2, a significant upswing during 2003q3 – 2005q3, and again a significant economic improvement throughout 2005q4 – 2008q3. Moreover, the figure shows that the ECB adjusted its refinancing rate in lockstep with these movements in economic activity during 2000q1 – 2003q2 and 2005q4 – 2008q3, but kept it at 2% throughout 2003q3 – 2005q3.

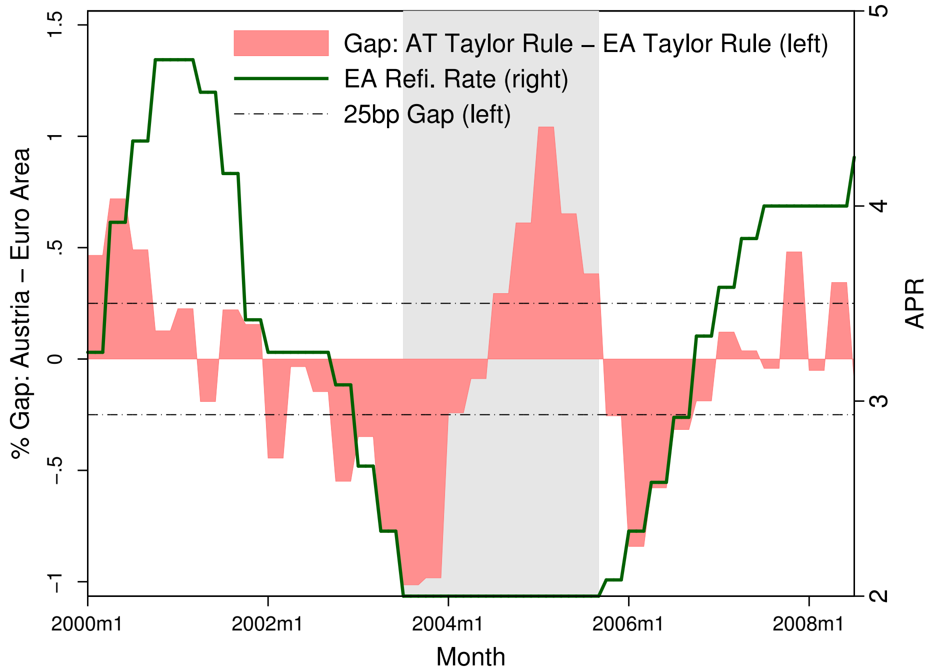
Thus, if the ECB's policy decisions were exogenous to Austrian economic activity, we could simply use this variation to construct our empirical test. However, while the ECB's mandate demands the stabilization of the euro area as a whole, and not any particular member country, Austria is part of the "core" of euro member countries. It is therefore hard to argue that the ECB refinancing rate is exogenous to Austrian economic activity.

Notice that the ECB's refinancing rate very closely follows the Taylor rule for the euro area almost throughout the entire sample. Thus, following Taylor's (1993) interpretation of this weighted average of inflation and output gaps, this illustrates the ECB's goal to stabilize the euro area as a whole. However, it turns out that Austrian economic activity was significantly different from average economic activity in the euro area during several times throughout 2000-2008. We therefore argue that economic decision makers, who predominantly care about Austrian economic activity, must have perceived the ECB's policy actions as exogenous, whenever Austria performed significantly better (worse) than the euro area as a whole.

The relevant actions in our analysis are Austrian banks' business lending decisions. When ranked by the amount of outstanding business loans, the top 4 out of 316 banks in our sample (99th percentile and above) provide 17% of all business lending, the top 18 (95th percentile and above), provide 47% of all business loans. The remaining 95% of Austrian banks are small and operate predominantly locally. Thus, we argue it is fair to assume that these banks predominantly care about business conditions in their local markets, rather than the euro area as a whole. The Austrian banking market therefore allows us to use variation in the difference between Austrian economic activity and the euro area, in order to identify the effects of the ECB's stance of monetary policy on Austrian banks' loan-portfolio risk.

Figure 6 illustrates the gap between economic activity in Austria and the euro area. We argue that, whenever this gap is sufficiently large, the ECB's policy choice is perceived exogenous by Austrian banks that operate predominantly locally. When this gap is very small, however, it may still be the case that the stance of policy is perceived as if the ECB was conducting policy to specifically stabilize Austria. In Taylor's (1993) interpretation, our baseline measure of economic activity simultaneously represents predicted nominal policy rates. Thus, since the ECB usually changes its policy rate in increments of 25 basis

Figure 6: Economic Activity: Austria vs. Euro Area



Notes: The dark shaded areas display the gap between economic activity in Austria (AT) and the Euro Area (EA), as specified in equation (8). The dashed lines indicate when this gap is 25 basis points in absolute value. The solid line is the ECB's main refinancing rate. The lightly shaded rectangular area illustrates the period during which the ECB refinancing rate was constant at 2%.

points, it is natural to expect that a gap of 25 basis points or more in absolute value will be perceived as an exogenous change in monetary policy relative to the Austrian economy. The dashed horizontal lines in Figure 6 indicate a gap of 25 basis points in absolute value.

One can see that there were a number of times during which the gap exceeds this threshold, both in the positive as well as negative range. Moreover, a comparison with Figure 5 makes apparent that the gap is highly positively correlated with Austrian economic activity in levels. Thus, a comparison of periods during which this gap is greater than 25bp, with periods during which it is less than -25bp, measures changes in Austrian economic activity, restricted to periods during which monetary policy is being perceived exogenous. We use precisely this variation to construct a formal empirical test for the predictions of our model.

4.1 Regression Framework

We start with defining the two indicator variables

$$MPR_t = \begin{cases} 1 & \text{if} \quad i_t^{ECB} = 2\% \\ 0 & \text{if} \quad i_t^{ECB} > 2\% \end{cases} \quad \text{and} \quad TRG_t^{\mu} = \begin{cases} 1 & \text{if} \quad gap_t^{TR} > \mu \\ 0 & \text{if} \quad gap_t^{TR} < -\mu \end{cases}, \tag{7}$$

where MPR_t indicates the monetary policy regime in year-month $t = (y, m)$.[19] We define the gap between Austrian and euro area economic activity, gap_q^{TR}, as

$$\begin{aligned} gap_q^{TR} \;=\; & \left[\bar{r}_q^{AT} + \bar{\pi}_q^{AT} + (1+\phi_\pi)(\pi_q^{AT} - \bar{\pi}_q^{AT}) + \phi_y(y_q^{AT} - \bar{y}_q^{AT})\right] \\ & - \left[\bar{r}_q^{EA} + \bar{\pi}_q^{EA} + (1+\phi_\pi)(\pi_q^{EA} - \bar{\pi}_q^{EA}) + \phi_y(y_q^{EA} - \bar{y}_q^{EA})\right], \end{aligned} \tag{8}$$

where π_q^j and y_q^j represent HICP inflation and real GDP in geographic region $j \in \{AT =$ Austria, $EA =$ euro area$\}$ in quarter q, respectively. $\bar{r}_q^j$, $\bar{y}_q^j$, and $\bar{\pi}_q^j$ denote equilibrium (or "target") levels of real interest rates, real GDP, and inflation in regions j. Finally, ϕ_π and ϕ_y represent policy weights on inflation and output stabilization, respectively.

In our baseline empirical analysis, we use Taylor's (1993) original suggestion of equal weights on output and inflation stabilization, i.e. $\phi_\pi = \phi_y = 0.5$. Further, we approximate all equilibrium values for each region j using a Hodrick-Prescott (HP) filter with a smoothing parameter of $\lambda = 1600$.[20] It is important to note that our identification strategy does not depend on the particular measure of "economic activity". However, the Taylor rule allows a straight forward interpretation of the resulting difference in economic activity, as defined in equation (8).

Borrowing the language from the literature on natural experiments (e.g., Card & Krueger 1994), we consider the period 2003q3 – 2005q3 ($MPR_t = 1$) as the "treatment" period and all the remaining periods between 2000 and 2008 ($MPR_t = 0$) as the "control" (or "counterfactual") periods.

The indicator TRG_t^{μ} serves two purposes in the design of our test: First, it acts as a "pseudo-randomization" tool since it isolates periods during which monetary policy was exogenous to the Austrian economy. We choose $\mu = 0.25$ as our baseline threshold to ensure exogeneity of the monetary policy instrument. Second, TRG_t^{μ} allows us to measure the effect of a switch from "worse than EA average" ($TRG_t^{\mu} = 0$) to "better than EA average" ($TRG_t^{\mu} = 1$) economic performance in Austria.

[19] Since werestrict our sample to the period 2000-2008, this indicator unambiguously identifies the low interest rate period of 2003-2005.

[20] See Appendix G for investigations on the robustness to alternative Taylor rule speficications.

Using the above definitions, we denote the expected change in banks' expected default rate due to a switch in economic conditions—from "worse than the EA" to "better than the EA"—relative to threshold μ and within a given policy regime $i \in \{0, 1\}$ as

$$\left.\frac{\Delta EDR}{\Delta TRG^{\mu}}\right|_{MPR=i} \equiv \mathrm{E}\left[EDR_{b,t}\,|TRG_t^{\mu} = 1, MPR_t = i\right] - \mathrm{E}\left[EDR_{b,t}\,|TRG_t^{\mu} = 0, MPR_t = i\right], \tag{9}$$

where $EDR_{b,t}$ is the empirical counterpart to definition (6) in Section 3.5. We then formally define the null hypothesis

$$H_0 : DD^{\mu} \equiv \left.\frac{\Delta EDR}{\Delta TRG^{\mu}}\right|_{MPR_t=1} - \left.\frac{\Delta EDR}{\Delta TRG^{\mu}}\right|_{MPR_t=0} = 0 \tag{10}$$

in order to test it against the alternative $H_1 : DD^{\mu} \neq 0$. In words, we are testing whether the period of extremely accommodating monetary policy between 2003 and 2005 ($TRG_t^{\mu} = 1$) changes the response of banks' loan-portfolio risk to an improvement in economic conditions.

If the mechanism envisioned in the model of Section 3 is indeed at work, we should expect to reject the null hypothesis defined in equation (10). Thus, we interpret this empirical test as a way to assess whether "too low interest rates for too long" have an effect on bank risk-taking.

Since the hypothesis in equation (10) only involves simple conditional expectations, it is easy to construct estimates $\hat{DD}^{\mu}$ based on conditional sample averages. However, the conditional expectations in equation (9) assume that all banks are equal and all aggregate economic conditions remain unchanged throughout the entire sample period. In particular, these simple conditional averages postulate that the changes in economic activity were of identical magnitude during all periods within our sample. As these assumptions are almost certainly violated, we would likely be reporting inconsistent estimates due to the omission of observed and unobserved bank heterogeneity as well as aggregate characteristics. We accommodate this concern by casting the above exercise into the following regression framework:

$$EDR_{b,t} = \alpha_0^{\mu} + \alpha_1^{\mu} \cdot MPR_t + \alpha_2^{\mu} \cdot TRG_t^{\mu} + DD^{\mu} \cdot [MPR_t \times TRG_t^{\mu}] + \beta^{\mu\prime} X_{b,t} + \epsilon_{b,t}^{\mu}, \tag{11}$$

where $(\alpha_0^{\mu}, \alpha_1^{\mu}, \alpha_2^{\mu}, DD^{\mu}, \beta^{\mu\prime})' \in \mathbb{R}^{4+\ell}$ is a coefficient vector, $X_{b,t}$ represents an $\ell \times 1$ vector of observable bank-specific and aggregate characteristics as well as a set of bank indicator variables, $\epsilon^{\mu}_{b,t}$ is a disturbance term with $E[\epsilon^{\mu}_{b,t}] = 0$, and $\mu = 0.25$.[21]

It is straightforward to show that DD^{μ} in regression model (11) is equivalent to the definition in equation (10) if and only if $\beta^{\mu\prime} = 0$.[22] Hence, if indeed there is no relevant systematic relation between individual bank characteristics and banks' expected default rates, then the OLS estimate $\hat{DD}^{\mu}$ is equivalent to taking simple conditional sample averages. If, on the other hand, bank and aggregate characteristics, $X_{b,t}$, influence expected default rates, the baseline estimates are inconsistent estimates of DD^{μ}.

Therefore, we alternatively estimate regression model (11), controlling for various bank-level characteristics as well as aggregate variables, that are likely to be influencing expected default rates. Section 4.2 briefly outlines our dataset, while Section 5 shows our empirical results and discusses the various characteristics included in $X_{b,t}$.

4.2 The Dataset

Our empirical analysis draws on four main data sources. First, in order to assess individual borrowers' creditworthiness, we utilize annual balance sheets and income statements from an unbalanced panel of 8,653 Austrian firms over the years 1993 to 2009. This data is collected by the Austrian National Bank (OeNB) in the course of its refinancing activities and is stored in a balance sheet register (BILA). The dataset also records various auxiliary characteristics, such as the firms' age, legal form, industry classification, and the number of employees. Furthermore, we observe whether a firm went bankrupt and, if so, on which date it filed for bankruptcy protection. Our sample records a total of 533 bankruptcies, which we employ as a proxy for the event of default.

Table 1 displays summary statistics of the firm-level characteristics utilized in this study. One can see that our sample consists of relatively large business whose total assets range from 5 million to 20 billion Euros. Further, 72% of the firms in the sample are limited liability companies (GmbH) and 36% operate in the manufacturing sector. On average, firms' liabilities amount to 66% of total assets while bank-liabilities make up 26% of total assets. Another variable of key importance for our analysis is the ratio of interest expenditure to "gross debt".[23] We interpret this ratio as a proxy for an average firm-level interest rate on firms' debt. In that sense, Austrian businesses in our sample, on

[21]Note that the vector of control variables combines both bank-specific and aggregate variables, i.e. $X_{b,t} = (\tilde{X}^{\prime}_{b,t}, Z^{\prime}_{t})^{\prime}$, where $\tilde{X}_{b,t}$ is an $\ell_1 \times 1$ vector of bank-specific variables (including fixed effects) and Z_t represents an $\ell_2 \times 1$ vector of aggregate variables, with $\ell = \ell_1 + \ell_2$.

[22]See Appendix D for details of the relation between equations (10) and (11).

[23]We define "gross debt" as liabilities net of long term reserves as well as provisions for pensions and other social transfers.

average (over time and across different types of debt), paid a real interest rate of 2.9%.[24]

In addition to annual firm specific information, the OeNB collects monthly data on individual loans between Austrian firms and banks in its central credit register (GKE).[25] The sample includes the stocks of credit by Austrian banks to Austrian firms whose total liabilities to Austrian banks exceed EUR 350,000, recorded at monthly frequency. Unfortunately, the OeNB's credit department does not record annual balance sheets and income statements for all of the firms whose financial obligations are in the GKE sample. This is due to the fact that GKE reports are mandated by law while reporting the balance sheet is voluntary. Consequently, our sample of firms is biased toward relatively large and sound businesses and, therefore, any results on risk-taking found in this study must be interpreted as an estimate of a lower bound for the true amount of risk-taking. In particular, we have access to a matched BILA-GKE sample for the years 2000 through 2009 which co-

[24]In order to reduce the impact of measurement error on our results we drop "implausible" observations, such as negative values for total assets, entries where detailed balance sheet positions don't correctly sum up to reported aggregates, etc. Further, we identify observations that exceed five times the distance between the 5th and 95th percentile of the cross-sectional distribution in either direction as statistical outliers. We run our empirical analyses with and without the identified outliers and find no significant qualitative differences, yet we believe the "clean" dataset to be more representative of the average firm's characteristics.

[25]Details on the data collection criteria can be found in the official standards for reporting to the central credit register (Großkreditevidenz), which are publicly available at http://www.oenb.at/. The individual data on both firms and banks are strictly confidential. Access to the anonymized individual data, as employed in this study, is granted by the OeNB's credit department on a case-by-case basis. Contact information can be found at www.oenb.at/.

Table 1: Summary Statistics (BILA)

	Obs.	Mean	Std. Dev.	Min	p^{25}	p^{75}	Max
Firm-Level Information (BILA): 1993 – 2009							
Accounting Ratios							
Liab./Assets	47673	0.659	0.227	0.000	0.519	0.835	1.000
Bank Liab./Assets	47661	0.260	0.240	0.000	0.030	0.426	1.000
Liab. Short/Assets	47661	0.296	0.213	0.000	0.135	0.421	1.000
Liq. Assets/Liab Short	47153	1.732	2.037	0.000	0.895	1.868	25.729
Acc. Payab./Net Sales	45581	0.089	0.124	0.000	0.029	0.103	1.531
Gross Profit/Exp. Labor	42420	3.051	3.778	-8.135	1.642	2.895	45.339
Ord. Bus. Inc./Assets	47652	0.059	0.115	-1.479	0.005	0.098	1.412
Exp. Interest/Gross Debt	47509	0.029	0.024	0.000	0.013	0.040	0.356
Legal Form							
AG	47673	0.113	0.316	0.000	0.000	0.000	1.000
GmbH	47673	0.722	0.448	0.000	0.000	1.000	1.000
KG	47673	0.127	0.333	0.000	0.000	0.000	1.000
Other	47673	0.038	0.190	0.000	0.000	0.000	1.000
Industry							
Manufacturing	47673	0.360	0.480	0.000	0.000	1.000	1.000
Construction	47673	0.056	0.231	0.000	0.000	0.000	1.000
Wholesale & Trade	47673	0.223	0.416	0.000	0.000	0.000	1.000
Transportation & Storage	47673	0.041	0.199	0.000	0.000	0.000	1.000
Prof., Scient., & Tech.	47673	0.080	0.271	0.000	0.000	0.000	1.000
Admin. & Support	47673	0.014	0.119	0.000	0.000	0.000	1.000
Other	47673	0.225	0.418	0.000	0.000	0.000	1.000
Age (years)	47473	18.871	17.661	0.000	7.000	26.000	140.000
Total Assets (Bill. Euros)	47673	0.071	0.374	0.000	0.005	0.037	20.149
Insolvent within							
1 year	47673	0.001	0.032	0.000	0.000	0.000	1.000
2 years	47673	0.003	0.052	0.000	0.000	0.000	1.000
3 years	47673	0.005	0.068	0.000	0.000	0.000	1.000
4 years	47673	0.007	0.082	0.000	0.000	0.000	1.000
5 years	47673	0.009	0.093	0.000	0.000	0.000	1.000

Notes: Our measures for firm's legal form, industry as well as insolvency are indicator variables taking the values 0 and 1. The legal form GmbH represents limited liability companies, AG stands for Aktiengesellschaft (equity firms), and KG refers to Kommanditgesellschaft (limited partnerships with at least one fully liable partner). The insolvency indicators summarized here are defined in equation (33). The columns labeled with p^{25} and p^{75} display the 25^{th} and 75^{th} percentiles, respectively.

Table 2: Summary Statistics (GKE, MONSTAT, & ECB)

	Obs.	Mean	Std. Dev.	Min	p^{25}	p^{75}	Max
Bank-Level Information (GKE and MONSTAT): 2000 – 2008							
$EDR_{b,t}$	27082	0.524	0.643	0.000	0.232	0.621	18.462
Bank: Capitalization (1-5)							
Cap. 1	27082	0.142	0.349	0.000	0.000	0.000	1.000
Cap. 2	27082	0.183	0.386	0.000	0.000	0.000	1.000
Cap. 3	27082	0.350	0.477	0.000	0.000	1.000	1.000
Cap. 4	27082	0.296	0.457	0.000	0.000	1.000	1.000
Cap. 5	27082	0.029	0.168	0.000	0.000	0.000	1.000
Bank: Cash Ratio (1-3)							
Cash Rat. 1	27082	0.318	0.466	0.000	0.000	1.000	1.000
Cash Rat. 2	27082	0.394	0.489	0.000	0.000	1.000	1.000
Cash Rat. 3	27082	0.288	0.453	0.000	0.000	1.000	1.000
Bank: Size by Assets (1-3)							
Size 1	27082	0.661	0.473	0.000	0.000	1.000	1.000
Size 2	27082	0.256	0.437	0.000	0.000	1.000	1.000
Size 3	27082	0.082	0.275	0.000	0.000	0.000	1.000
Bank: No. of Loans	27082	26.549	102.893	1.000	3.000	12.000	1847.000
Aggregate Characteristics (ECB): 2000 – 2008							
i_q^{ECB}	27082	3.094	0.911	2.000	2.000	4.000	4.750
gap_q^{TR}	27082	0.215	0.949	-1.267	-0.474	0.604	2.934
$y_q - y_q^*$	27082	0.316	1.326	-1.563	-0.804	1.607	3.091
π_q^{AT}	27082	2.025	0.605	1.067	1.733	2.200	3.700
$i_q^{10,AT} - i_q^{3,EA}$	27082	1.039	0.795	-0.410	0.330	1.653	2.263
$i_q^{10,AT} - i_q^{10,EA}$	27082	0.020	0.053	-0.057	-0.030	0.063	0.130
AT Bank-Loans/Total Assets	27082	0.358	0.015	0.325	0.350	0.369	0.385
GKE Credit/AT Bank-Loans	27082	0.431	0.022	0.395	0.408	0.456	0.462

Notes: Our measures for banks' capitalization, cash ratio, and size by assets are indicator variables taking the values 0 and 1. The columns labeled with p^{25} and p^{75} display the 25^{th} and 75^{th} percentiles, respectively.

vers 316 Austrian banks and 6,815 firms whose detailed characteristics are also recorded in BILA. Table 2 reports summary statistics for this matched sample.

In addition to the raw data, Table 2 also summarizes the expected default rate within banks' business-loan portfolios ($EDR_{b,t}$) as well as the Austrian Taylor Rule gap (gap_q^{TR}) whose construction is outlined in Appendix B and equation (8), respectively.

EMU member states are further required to collect detailed balance sheet information on their monetary and financial institutions (MONSTAT).[26] Unfortunately, due to Austrian data confidentiality restrictions, we were not allowed to match this detailed bank-level information at the bank level to our sample of matched firm-bank pairs. However, we were allowed to merge discrete categories of key bank-level characteristics that vary on an annual frequency. The top panel of Table 2 illustrates our measures for banks' capitalization, liquidity, and size for the matched BILA-GKE sample.[27]

Finally, all aggregate data are drawn from the ECB's statistical data warehouse.[28] The bottom panel of Table 2 reports summary statistics on these aggregate variables. An important statistic for the purpose of this study is the average proportion of business loans within banks' balance sheets, which was 36%, on average, and was ranging between 33% and 39% between 2000 and 2008.

5 Empirical Results

Using the dataset described in Section 4.2 we perform the empirical tests outlined in Section 4.1. Table 3 summarizes the resulting estimates for the "differences in differences", $\hat{DD}^{\mu}$, as well as the associated standard errors in parentheses below each estimate. Based on simple conditional averages, as shown in column (1) of Table 3, we estimate the average expected default rate to increase by about 20 basis points. This effect is sizable as it amounts to roughly a 40% increase relative to an overall sample average of 0.525%.

Further, our estimates indicate that expected default rates during the "counterfactual" periods were slightly decreasing in response to an improvement in economic conditions—both relative to the EA as well as in absolute terms. This finding is also consistent with the predictions of our model. During the counterfactual periods, ECB policy rates were sharply adjusted in lockstep with both Austrian as well as euro are economic activity.

[26]For details see http://europa.eu/legislation_summaries/economic_and_monetary_affairs/institutional_and_economic_framework/l25044_en.htm.

[27]The matching of the two datasets was conducted by the OeNB's credit department and the matched version was delivered to us in completely anonymized form.

[28]See http://sdw.ecb.europa.eu/.

Table 3: The Effect of "Too Low Interest Rates for Too Long" ($\mu = 0.25$)

Dep. Var.: $\text{EDR}_{b,t}$	All Banks		99%		95%	
2000q1-2008q3	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.562***	1.598**	0.562***	1.633**	0.564***	1.718**
	(0.0239)	(0.680)	(0.0243)	(0.692)	(0.0254)	(0.728)
MP_t	-0.0259	-0.0722***	-0.0268	-0.0730***	-0.0317	-0.0754***
	(0.0245)	(0.0264)	(0.0249)	(0.0268)	(0.0261)	(0.0281)
$GAP_t^{\text{tr},25}$	-0.124***	-0.0710	-0.124***	-0.0708	-0.125***	-0.0761
	(0.0252)	(0.0513)	(0.0256)	(0.0521)	(0.0268)	(0.0547)
$DD^{\text{tr},25}$	0.208***	0.157***	0.211***	0.159***	0.219***	0.170***
	(0.0376)	(0.0531)	(0.0381)	(0.0540)	(0.0399)	(0.0565)
No. Banks	316	316	312	312	300	300
Obs.	15827	15827	15587	15587	14867	14867
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
$\overline{EDR}_T$	0.525	0.525	0.526	0.526	0.527	0.527
$DD^{\text{tr},25}/\overline{EDR}_T$	0.397	0.300	0.401	0.303	0.416	0.322
Bank FEs	no	yes	no	yes	no	yes
Controls	no	yes	no	yes	no	yes

Notes: Standard errors are clustered on bank and reported in parentheses underneath the coefficients. Significance levels are indicated by * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. Columns (1) and (2) include all banks, (2) and (3) restrict the sample to the top 99% of banks (in terms of average lending volume), and columns (5) and (6) include the top 95%. Full regression tables with coefficients for all control variables in columns (2), (4), and (6) are reported in Appendix C.

Thus, our estimates suggest that banks' portfolios do not deteriorate if interest rates are sharply reduced, as long as economic activity is declining as well. This further implies that very low interest rates per se do not necessarily imply any systematic increase in banks' default risk. Only if there is a significant improvement in economic activity *togther* with sufficiently low and unchanged interest rates, do banks allow more default risk in their loan portfolios.

As argued in the previous section, we have reason to believe that these baseline estimates are likely inconsistent, due to the omission of bank-level and aggregate characteristics. However, column (2) of Table 3 illustrates that controlling for various aggregate and bank-level characteristics does not change the qualitative result.[29] Notice, however, that the change in expected default rates during the "counterfactual" periods is now statistically insignificant. This

suggests that the policy actions in the "counterfactual" periods, during which the ECB adjusted policy rates in lockstep with economic activity, left expected default risk within the banking sector largely unchanged.

[29]Full regression tables, reporting all coefficient estimates for the included control variabels, are reported in Appendix C.

Yet, the overall qualitative result of a large differential impact (between "treatment" and "counterfactual") remains consistent with the model's predictions. The full regression results are displayed in Appendix C and we will briefly discuss the additional control variables in the following paragraphs.

Our first concern is the different magnitude of the changes in economic activity during the treatment and control periods (see Figure 5). Thus, to ensure that our results are not driven by these differences we include the levels of Austrian output gaps, $y_q^{AT} - \bar{y}_q^{AT}$, and inflation, π_q^{AT}, as our first set of control variables.

Further, we presume that both term and country-risk-premia might have a significant influence on the degree of risk in banks' portfolios. We accommodate this concern by including the spread between Austrian 10-year bond yields and 3-month EA money market rates, $i_q^{10,AT} - i_q^{3,EA}$, to proxy term-spreads, and the spread between the yields of Austrian 10-year and EA 10-year bonds, $i_q^{10,AT} - i_q^{10,EA}$, to control for country-risk premia.

As we point out in our discussion of the most recent credit cycle in Austria (Appendix E), there was a tremendous increase in real business-lending activity toward the end of the "treatment period". To make sure that the measured increase in expected default rates is not entirely driven by this significant credit expansion during the year 2005, we also include real Austrian business-loan growth, as depicted in panel (B) of Figure 7.

Another concern is the restriction of our analysis to business-lending only. While business lending in Austria amounts to roughly 40% of all lending, alternative sources of external funding became significantly more popular throughout our sample period from 2000 through 2008. Thus, we include the aggregate fraction of Austrian business lending in banks' total assets to accommodate this concern.

Apart from concerns about aggregate changes in the Austrian economy we are also worried about changes in the aggregate representativeness of our unbalanced panel of firm-bank pairs. For that reason we include the ratio of aggregate lending within our GKE sample as a fraction of overall Austrian business lending.

Finally, after controlling for the relevant aggregate characteristics, we are further concerned about bank-level heterogeneity, that might be driving the results. Hence, we include control variables for banks' degree of capitalization, cash ratio, and size by total assets. On top of that, we add a complete set of bank fixed effects to additionally accommodate for unobserved bank heterogeneity. These bank-level control variables in part capture the effects of changes in financial regulation that were going on during this period—first and foremost the structural changes due to (the preparation for) the Basel II accord, which became legally binding in Austria as of January 1, 2007.

Given this rich set of control variables, we are confident, that the effect identified by our empirical analysis, as illustrated in columns (1) and (2) of Table 3, is indeed capturing a causal effect of extremely low and constant policy interest rates during the years 2003 through 2005 on Austrian banks' risk-taking behavior.

5.1 Robustness Checks

Despite the many aggregate control variables, discussed in the previous section, one might raise the concern that the period between 2000 and 2002 was quite different from the period between 2006 and 2008, along other dimensions, not controlled for here. Thus, we investigate whether there is a difference in the measured effect, if we restrict the control periods to either "before" (2000q1-2003q2) or "after" (2005q4 – 2008q3) the "treatment" period, respectively. Panels (A) and (B) of Table 4 illustrate the results of the two alternative thought experiments and reveal a qualitatively equivalent result.

These alternative experiments reveal two important insights: First, they illustrate that our implicit symmetry assumption (with respect to the economic improvement) plays no important role. The "before" period features a substantial economic downturn while the "after" period displays a significant economic upswing. Yet, the differential impact on banks loan default-risk relative to the "treatment" period is virtually the same. While the after period features a stronger differential effect, both estimates are sizably positive and highly significant.

Second, they rule out financial innovation, systematic changes in risk-management practices, as well as more restrictive capital adequacy requirements—in preparation for the Basel II accord—as the main drivers for the increase in loan-portfolio-risk. In Austria, all these structural changes took place during the "treatment" period. Thus, if they were driving the results, then one should see a significant "difference in differences" for the "before" comparison but not for the "after" comparison—a hypothesis that we can confidently reject.

Furthermore, our identification strategy critically hinges on the assumption that Austrian banks predominantly base their lending decisions on economic conditions in Austria. As argued in the previous sections, the majority of Austrian banks is very small, and most business lending is concentrated within largest 5% of banks. Columns (3)-(6) of Tables 3 and 4 show our test when excluding the largest 1% of banks (17% of all lending) as well as the largest 5% of banks (47% of all lending). The exclusion of these banks does not make any noticeable qualitative difference.

All results presented here are conditional on our particular measure of economic ac-

Table 4: The Effect of "Too Low Interest Rates for Too Long" ($\mu = 0.25$)

Dependent Variable: $\text{EDR}_{b,t}$	All Banks		99%		95%	
(A) Before: 2000q1-2005q3						
Constant	0.576***	1.149	0.575***	1.189	0.573***	1.218
	(0.0330)	(0.827)	(0.0335)	(0.843)	(0.0351)	(0.890)
MP_t	-0.0403*	-0.00755	-0.0401*	-0.00611	-0.0412*	-0.00484
	(0.0229)	(0.0337)	(0.0232)	(0.0343)	(0.0244)	(0.0361)
$GAP_t^{\text{tr},25}$	-0.0990**	-0.132***	-0.0974**	-0.129**	-0.0948**	-0.127**
	(0.0390)	(0.0499)	(0.0397)	(0.0508)	(0.0417)	(0.0535)
$DD^{\text{tr},25}$	0.183***	0.182**	0.184***	0.182**	0.189***	0.185**
	(0.0438)	(0.0783)	(0.0446)	(0.0797)	(0.0469)	(0.0839)
No. Banks	296	296	292	292	280	280
Obs.	10567	10567	10399	10399	9895	9895
Model p-value	0.000	0.010	0.000	0.011	0.000	0.014
$\overline{EDR}_T$	0.525	0.525	0.526	0.526	0.527	0.527
$DD^{\text{tr},25}/\overline{EDR}_T$	0.349	0.346	0.351	0.346	0.359	0.351
(B) After: 2003q3-2008q3						
Constant	0.549***	1.797	0.550***	1.848	0.555***	1.992
	(0.0277)	(1.524)	(0.0281)	(1.551)	(0.0293)	(1.628)
MP_t	-0.0133	-0.284***	-0.0152	-0.290***	-0.0234	-0.302***
	(0.0363)	(0.0627)	(0.0368)	(0.0636)	(0.0384)	(0.0667)
$GAP_t^{\text{tr},25}$	-0.154***	-0.0150	-0.155***	-0.0177	-0.159***	-0.0314
	(0.0284)	(0.119)	(0.0288)	(0.121)	(0.0300)	(0.128)
$DD^{\text{tr},25}$	0.238***	0.239***	0.242***	0.246***	0.253***	0.267***
	(0.0434)	(0.0720)	(0.0440)	(0.0736)	(0.0459)	(0.0774)
No. Banks	312	312	308	308	296	296
Obs.	10877	10877	10721	10721	10253	10253
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
$\overline{EDR}_T$	0.525	0.525	0.526	0.526	0.527	0.527
$DD^{\text{tr},25}/\overline{EDR}_T$	0.454	0.456	0.460	0.468	0.480	0.507
Bank FEs	no	yes	no	yes	no	yes
Controls	no	yes	no	yes	no	yes

Notes: Standard errors are clustered on bank and reported in parentheses underneath the coefficients. Significance levels are indicated by * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. Columns (1) and (2) include all banks, (2) and (3) restrict the sample to the top 99% of banks (in terms of average lending volume), and columns (5) and (6) include the top 95%. Full regression tables with coefficients for all control variables in columns (2), (4), and (6) are reported in Appendix C.

tivity. We alternatively use inflation, as well as real GDP gaps individually, to compute the AT-EA gap measure and do not find any significant qualitative differences.[30]

Finally, we check whether the particular threshold of $\mu = 0.25$ plays a significant role and use $\mu = 0.15$, $\mu = 0.2$ and $\mu = 0.3$ as alternatives. Again, neither of these sensitivity checks substantially change the qualitative results.[31]

[30] These results are reported in Appendix F.

[31] These results are reported in Appendix C.

6 Concluding Remarks

Our theoretical and empirical findings point to a channel of the transmission mechanism of monetary policy, which is triggered by an extended period of extremely cheap short-term refinancing conditions *combined* with a significant economic improvement. Our model makes clear that this channel works on top of the traditional transmission channels. Most importantly, the classic credit channel works through an improvement in *every* borrower's balance sheet. Within our model, such an effect is equivalent to a "leftward" shift in the cross-sectional distribution of borrowers' intrinsic default risk. Since the bank's profits from a borrower of given quality are independent of the distribution of borrowers across risk classes, the highest "acceptable" borrower-level default probability will remain unchanged by this shift. Thus, the classic credit channel leads to an increase in lending but it cannot cause an increase in measured bank portfolio-risk, while the mechanism illustrated in this paper does.

Borio & Zhu (2008) have recently dubbed this phenomenon the "risk-taking channel" of monetary policy and—in contrast to the traditional transmission channels—this mechanism has the property that its consequences for real activity need not materialize within a short period of time.[32] In fact, as the direct effect of this mechanism is a deterioration of financial institutions' risk-positions, it might not result in any significant implications for the real economy under "normal" circumstances. However, in the unlikely event of a significant disruption of financial markets—like the failure of Lehman Brothers in the fall of 2008, which resulted in a global panic among investors roughly 3 years after the deterioration of banks' balance sheets had taken place—more "fragile" bank balance sheets might significantly amplify the repercussions of a "shock" to the financial system.

Again, the model of Section 3 gives insight into why this may be. If the cost of external funds is in the neighborhood of the threshold, at which banks are indifferent between screening or offering a pooling contract, economic shocks are amplified in both directions, positive and negative. In the same way that a boost in investor wealth—say, through an asset bubble—may cause an excessive credit expansion, a shock of equal magnitude in the opposite direction—like the bursting of an asset bubble—would lead to an equally sharp reduction in credit. However, since bubbles usually form slowly but the bursting thereof is a sudden and drastic event, one should expect a quite asymmetric response in

[32]Traditional transmission channels tend to work fairly "quickly". See for instance Christiano et al. (1996) or Christiano et al. (2007), who find that real activity tends to respond within about a year to temporary movements in short term policy interest rates. Furthermore, the latter study also finds extremely quick responses of borrowers' net worth.

reality.

Moreover, the extremely risky balance sheets of financial institutions around the world in 2007-2008 significantly amplified the shock to available investor funds. Not only did the bursting of the housing bubble in various countries lead to a significant reduction in investors' asset wealth across the globe but, on top of that, investor's confidence in financial institutions—that had made excessively risky bets—was drastically reduced at the same time (Brunnermeier 2009). In the language of the model in Section 3 this would result in an even stronger reduction of available investor funds and thus an even stronger increase in the cost of external funds.

It is thus not surprising that Nouriel Roubini and Stephen Mihm compare the mechanisms that lead to the 2007/2008 financial turmoil to the fault lines that eventually lead to an earthquake (Roubini & Mihm 2010, p. 62):

> [...] [T]he pressures build for many years, and when the shock finally comes, it can be staggering. [...] The collapse revealed a frightening truth: the homes of subprime borrowers were not the only structures standing on the proverbial fault line; countless towers of leverage and debt had been built there too.

Moreover, the deterioration of banks' balance sheets during the period 2003 through 2005 was likely to be significantly amplified by the tremendous increase in the quantity of lending, that is consistent with traditional channels of monetary policy transmission and illustrated in Figure 7. This amplification is likely to have happened, as the outstanding boom in lending activity significantly increased the size of the financial sector, and hence, made any sudden failure of this market even more detrimental to the overall economy.

Thus, the peculiar nature of this so-called "risk-taking channel" suggests that future monetary policy should possibly more explicitly take its effects on financial stability—due to its influence on risk-taking behavior of financial institutions—into account. Whether this calls for a policy of "leaning against the wind of financial imbalances" (Bini Smaghi 2011), or whether tighter coordination with prudential regulation is the appropriate route for future policy, goes beyond the scope of this paper.

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Appendices

A Model Details

If the bank chooses to incur the screening cost C^S the optimal choice is the solution to the following optimization problem:

$$\pi^S = \max_{R(\lambda),L(\lambda),\Lambda} \left\{ \int_\Lambda L(\lambda) \left[(1-\lambda)R(\lambda) - R^d\right] dG(\lambda) \right\} - C^S \tag{12}$$

such that

$$(1-\lambda)\left[F(K(\lambda)) - L(\lambda)\cdot R(\lambda)\right] \geq 0 \tag{13}$$

$$K(\lambda) + C^F = L(\lambda), \tag{14}$$

where equations (13) and (14) represent the participation constraint and define the loan size for each firm $\lambda \in \Lambda$, respectively. Thus, we have that

$$R(\lambda) = \frac{F(K(\lambda))}{K(\lambda) + C^F} \tag{15}$$

and, together with definition (14), the bank's profit expected from a loan advanced to firm λ is given by

$$\pi^S(\lambda) = (1-\lambda)F(K(\lambda)) - R^d \cdot \left[K(\lambda) + C^F\right]. \tag{16}$$

Since $F(K)$ is monotonically increasing and strictly concave $\pi^S(\lambda)$ is strictly concave in K. Thus, the optimal loan contract tailored for firm λ needs to satisfy the first order condition

$$(1-\lambda)F'(K(\lambda)) = R^d \tag{17}$$

which directly implies that $K(\lambda)$ is decreasing in λ. This implies the following Lemmas.

Lemma 1 *Assume that $F(\cdot)$, $R^d > 1$, and $C^F > 0$ are such that $\pi^S(0) > 0$. Then, under perfect information an optimal loan contract for firm $\lambda \in [0,1]$ satisfies the following properties:*

(i) $K(\lambda) > 0$ *for* $0 \leq \lambda < 1$ *and* $\lim_{\lambda \to 1} K(\lambda) = 0$

(ii) $\frac{\partial K(\lambda)}{\partial \lambda} < 0$ *for* $0 \leq \lambda < 1$ *and* $\lim_{\lambda \to 1} \frac{\partial K(\lambda)}{\partial \lambda} = 0$

(iii) $\frac{\partial K(\lambda)}{\partial R^d} < 0$, $\frac{\partial^2 K(\lambda)}{\partial R^d \partial \lambda} \gtreqless 0$, *for any fixed* $\lambda \in [0,1)$, *with* $\frac{\partial^2 K(\lambda)}{\partial R^d \partial \lambda} > 0$ *if* $F''(K(\lambda)) > \frac{F'''(K(\lambda))}{F''(K(\lambda))}$.

(iv) $\frac{\partial \pi^S(\lambda)}{\partial \lambda} < 0$ *for* $0 \leq \lambda < 1$ *and* $\lim_{\lambda \to 1} \frac{\partial \pi^S(\lambda)}{\partial \lambda} = 0$.

Proof of Lemma 1 Assume that $C^F > 0$, $F(K) \geq 0$, $F'(K) > 0$, $F''(K) < 0$, $F'''(K) > 0$, and $\lim_{K \to 0} F'(K) = \infty$.

(i)-(ii) For a bank to receive positive profits from a loan advanced to a risk-less firm, i.e. with $\lambda = 0$, it is strictly necessary that a positive amount of capital is installed, i.e. $K(0) > 0$. This is immediate from equation (4), as profits from a loan with $K(0) = 0$ would yield profits of $\pi^S = -R^d C^F < 0$. Further, notice that in an optimal contract equation (17) has to be satisfied. By the implicit function theorem this first order condition implies that $\frac{\partial K}{\partial \lambda} = \frac{F'(K)}{(1-\lambda)F''(K)} < 0$. Further, equation (17) requires that

$$F'(K(\lambda)) = \frac{R^d}{1-\lambda}. \tag{18}$$

Since the right hand side of this equation tends to positive infinity as λ approaches 1, i.e. $\lim_{\lambda\to 1}\frac{R^d}{1-\lambda}=\infty$, we must have that $\lim_{\lambda\to 1}F'(K(\lambda))=\infty$. This directly implies that the amount of capital must tend to zero as λ approaches 1, i.e. $\lim_{\lambda\to 1}K(\lambda)=0$.

(iii) For fixed $\lambda\in[0,1)$, the first order condition for capital (17) and the implicit function theorem imply that

$$\frac{\partial K(\lambda)}{\partial R^d}=\frac{1}{(1-\lambda)F''(K(\lambda))}<0 \tag{19}$$

and

$$\frac{\partial^2 K(\lambda)}{\partial R^d\partial\lambda}=\frac{F''(K(\lambda))-(1-\lambda)F'''(K(\lambda))K'(\lambda)}{[(1-\lambda)F''(K(\lambda))]^2}\gtreqless 0, \tag{20}$$

with $\frac{\partial^2 K(\lambda)}{\partial R^d\partial\lambda}>0$ if $F''(K(\lambda))>\frac{F'''(K(\lambda))}{F''(K(\lambda))}$. This follows from the assumption that $F'''(K)>0$ and $K'(\lambda)<0$ by part (i).

(iv) From equation (4) it follows that

$$\begin{aligned}\frac{\partial\pi^S(\lambda)}{\partial\lambda} &= -F(K(\lambda))+\left[(1-\lambda)F'(K(\lambda))-R^d\right]\frac{\partial K}{\partial\lambda}(\lambda)\\ &= -F(K(\lambda))<0,\end{aligned} \tag{21}$$

where the second equality follows from the first order condition (17). Since $\lim_{\lambda\to 1}K(\lambda)=0$ it immediately follows that $\lim_{\lambda\to 1}\frac{\partial\pi^S(\lambda)}{\partial\lambda}=-\lim_{\lambda\to 1}F(K(\lambda))=0$. QED.

Lemma 2 *Assume that* $F(\cdot)$, $R^d>1$, *and* $C^F>0$ *are such that* $\pi^S(0)>0$. *Further, let* $\{L(\lambda),R(\lambda)\}_{\lambda\in[0,1]}$ *be a menu of optimal contracts satisfying properties (i)-(iv) in Lemma 1. Then, there exists a unique* $\lambda^*\in(0,1)$ *such that*

(i) $\pi^S(\lambda)\geq 0$ *for all* $\lambda\leq\lambda^*$,

(ii) $\pi^S(\lambda)<0$ *for all* $\lambda>\lambda^*$, *and*

(iii) $\frac{\partial\lambda^*}{\partial R^d}<0$.

Proof of Lemma 2 Assume that $C^F>0$, $F(K)\geq 0$, $F'(K)>0$, $F''(K)<0$ and $\lim_{K\to 0}F'(K)=\infty$ and $\pi^S(0)>0$.

(i) - (ii) Since $\lim_{\lambda\to 1}K(\lambda)=0$ (Lemma 1) it follows that $\pi^S(1)=-R^dC^F<0$. Further, since $\pi^S(\lambda)$ is monotonically decreasing in λ on the interval $[0,1)$ (Lemma 1) there exists a unique $\lambda^*<0$, such that $\pi^S(\lambda^*)=0$. By the same reasoning it must be that $\pi^S(\lambda)\geq 0$ for all $\lambda\leq\lambda^*$, and $\pi^S(\lambda)<0$ for all $\lambda>\lambda^*$.

(iii) The cut-off default risk is implicitly defined by the equation $(1-\lambda^*)F(K(\lambda^*)) - R^d\left[C^F + K(\lambda^*)\right] = 0$. By the implicit function theorem this condition implies that

$$\begin{aligned}\frac{\partial \lambda^*}{\partial R^d} &= \frac{K(\lambda^*) + C^F}{\left[(1-\lambda^*)F'(K(\lambda^*)) - R^d\right]\frac{\partial K}{\partial \lambda}(\lambda^*) - F(K(\lambda^*))} \\ &= -\frac{K(\lambda^*) + C^F}{F(K(\lambda^*))} < 0,\end{aligned} \tag{22}$$

where the second equality follows from the first order condition (17). QED.

The properties illustrated in Lemma 2 immediately imply that banks will service customers in the interval $[0, \lambda^*]$ and will redline firms whose probability of default exceeds λ^*. Note that a fixed cost is but one means to achieve an interior cutoff probability of default. For instance, an outside option for the firms that yields nonzero utility to the firm's manager would also imply an interior cutoff. One example is the model by de Meza & Webb (1987). This result is formally stated in Corollary 1.

Corollary 1 *Assume that $F(\cdot)$, $R^d > 1$, and $C^F > 0$ are such that $\pi^S(0) > 0$. Further, let $G(\lambda)$ be nondegenerate. Then,*

(i) the optimal set of firms financed by the bank is given by $\Lambda^* = [0, \lambda^*]$, where λ^* is defined in Lemma 2, and

(ii) $\frac{\partial R(\lambda)}{\partial \lambda} > 0$ for all $\lambda \in [0, \lambda^*)$.

Proof of Corollary 1 Assume that $C^F > 0$, $F(K) \geq 0$, $F'(K) > 0$, $F''(K) < 0$ and $\lim_{K\to 0} F'(K) = \infty$ and $\pi^S(0) > 0$.

(i) Using the properties of Lemma 2 we can rewrite the bank's optimization problem as

$$\pi^S = \max_{K(\lambda),\lambda^*} \left\{ \int_0^{\lambda^*} (1-\lambda)F(K(\lambda)) - R^d \cdot \left[K(\lambda) + C^F\right] dG(\lambda) \right\} - C^S. \tag{23}$$

The first order condition with respect to $K(\lambda)$ is given by equation (17) and the first order condition with respect to λ^* is given by

$$(1-\lambda^*)F(K(\lambda^*)) - R^d\left[C^F + K(\lambda^*)\right] = 0, \tag{24}$$

which is precisely the implicit definition of λ^* used in Lemma 2. Thus, by Lemma 2, the optimal set of borrowers is $\Lambda^* = [0, \lambda^*] \subset [0, 1]$.

(ii) The optimal interest rate $R(\lambda)$ has to satisfy equation (15) which implies that

$$\frac{\partial R}{\partial \lambda}(\lambda) \quad = \quad -\frac{\frac{\partial K}{\partial \lambda}(\lambda)}{K(\lambda)+C^F}\left(F(K(\lambda)) - F'(K(\lambda))\left[K(\lambda)+C^F\right]\right). \tag{25}$$

Thus, since $\frac{\partial K}{\partial \lambda} < 0$ for all $\lambda \in [0,1)$ (Lemma 1), we have that

$$\text{sign}\left(\frac{\partial R}{\partial \lambda}(\lambda)\right) = \text{sign}\left(F(K(\lambda)) - F'(K(\lambda))\left[K(\lambda)+C^F\right]\right). \tag{26}$$

First, notice that $\frac{\partial R}{\partial \lambda}(\lambda^*) = 0$. To see why, combine the first order condition for capital (17) and the first order condition for the maximum risk cut-off (24), which implies that $F(K(\lambda^*)) = F'(K(\lambda^*))\left[K(\lambda^*)+C^F\right]$. Further, notice that

$$F(K(\lambda)) - F'(K(\lambda))\left[K(\lambda)+C^F\right] \geq (1-\lambda)\left[F(K(\lambda)) - F'(K(\lambda))\left[K(\lambda)+C^F\right]\right], \tag{27}$$

for all $\lambda \in [0,\lambda^*)$, where the equality holds at $\lambda = 0$. The right hand side of equation (27) simply represents the profits per firm, $\pi^S(\lambda)$, after imposing the first order condition for capital (17). Thus, by Lemma 2, it follows that $\frac{\partial R}{\partial \lambda}(\lambda) > 0$ for all $\lambda \in [0,\lambda^*)$. QED.

If the bank chooses to not incur the screening cost C^S it can only offer a single contract (R,L) that is identical for every customer. Thus, the bank's optimal contract without screening applicants solves the optimization problem

$$\pi^{NS} = \max_{R,L}\left\{\int_0^1 (K+C^F)\left[(1-\lambda)R - R^d\right] dG(\lambda)\right\} \tag{28}$$

such that

$$(1-\lambda)\left[F(K) - (K+C^F)\cdot R\right] \quad \geq \quad 0.$$

The solution to this problem is summarized in Lemma 3.

Lemma 3 *Assume that $F(\cdot)$, $R^d > 1$, and $C^F > 0$ are such that $\pi^S(0) > 0$. Further let $G(\lambda)$ be nondegenerate and define the average probability of default in the population of firms as $\bar{\lambda} \equiv \int_0^1 \lambda dG(\lambda)$. Then, the optimal contract without screening is such that*

(i) $K = K(\bar{\lambda})$ *and*

(ii) $R = R(\bar{\lambda})$

where $K(\cdot)$ and $R(\cdot)$ are the solutions to the optimization problem with screening, characterized in Lemmas 1 and 2.

Proof of Lemma 3

(i)-(ii) Optimization problem (28) can be rewritten as

$$\begin{aligned}\pi^{NS} &= \max_K \left\{ \int_0^1 (1-\lambda)F(K) - (K+C^F)R^d dG(\lambda) \right\} \\ &= \max_K \left\{ F(K) \int_0^1 (1-\lambda)dG(\lambda) - (K+C^F)R^d \right\} \\ &= \max_K \left\{ (1-\bar{\lambda})F(K) - (K+C^F)R^d \right\} \\ &= \max_K \left\{ \pi^S(\bar{\lambda}) \right\}. \end{aligned} \tag{29}$$

Thus, the optimization problem without screening is equivalent to the optimization problem for the optimal individual contract for the average borrower $\bar{\lambda} \equiv \int_0^1 \lambda dG(\lambda)$. Hence, the solution to this problem is given by $K = K(\bar{\lambda})$ and $R = R(\bar{\lambda})$, where $R(\cdot)$ and $K(\cdot)$ are characterized in Lemmas 1 and 2, as well as Corollary 1. QED.

A.1 The Optimal Screening Strategy

To see why the cutoff interest rate, $\tilde{R}^d$, as depicted in panel (A) of Figure 3, may exist consider the difference between profits in the two alternative second stage scenarios:

$$\begin{aligned}\Delta\pi(R^d) &\equiv \pi^{NS}(R^d) - \pi^S(R^d) \\ &= (1-\bar{\lambda})F(K(\bar{\lambda}, R^d)) - R^d \left[C^F + K(\bar{\lambda}, R^d)\right] \\ &\quad - \left[\int_0^{\lambda^*(R^d)} (1-\lambda)F(K(\lambda, R^d)) - R^d \left[C^F + K(\lambda, R^d)\right] dG(\lambda) - C^S \right] \end{aligned} \tag{30}$$

This generally highly nonlinear and non-monotonic function can be decomposed into three parts, corresponding to the *intensive* and the *extensive* margin of adjustment to the bank's loan portfolio, as well as the cost of *screening*, respectively.

$$
\begin{aligned}
\Delta\pi(R^d) \;=\;& \underbrace{(1-\bar{\lambda})F(K(\bar{\lambda},R^d)) - R^d K(\bar{\lambda},R^d) - \left[\int_0^{\lambda^*(R^d)} (1-\lambda)F(K(\lambda,R^d)) - R^d K(\lambda,R^d) dG(\lambda)\right]}_{\text{intensive margin}} \\
& \underbrace{- C^F R^d \left[1 - \int_0^{\lambda^*(R^d)} (1-\lambda) dG(\lambda)\right]}_{\text{extensive margin}} \\
& + \underbrace{C^S}_{\text{screening cost}}
\end{aligned} \tag{31}
$$

We explain the properties of this function for each of its three components separately:

The Intensive Margin Suppose that $C^F = C^S = 0$, i.e. there are no fixed and screening costs, which implies that the extensive margin as well as the cost considerations for screening disappear. Equation (31) then collapses to

$$
\Delta\pi(R^d)\big|_{C^F=C^S=0} = \pi^{NS}(\bar{\lambda},R^d) - \int_0^1 \pi^{NS}(\lambda,R^d) dG(\lambda) < 0, \tag{32}
$$

where the inequality follows from the fact that $\pi^{NS}(\lambda, R^d)$ is strictly convex in λ (Lemma 1) and Jensen's inequality. Notice that $\Delta\pi(R^d)\big|_{C^F=C^S=0}$ is the upper bound for the expression representing the intensive margin (the first line) in equation (31). This is because in the absence of a fixed cost, profits for any borrower λ are at least equal to zero. Thus, the expression in square brackets in the first line of equation (31) is increasing in λ^* and reaches its maximum value at $\lambda^* = 1$.

Consequently, the intensive margin alone gives the bank an incentive to screen irrespective of R^d. However, the magnitude of this incentive is non-monotonic in R^d. At very high levels of R^d, at which λ^* is very low, the intensive margin gives the bank a very powerful tool to improve profits in the case of perfect information. As λ^* increases with the decrease in R^d (Lemma 2), this benefit diminishes. At intermediate levels of R^d the slope of the profit function for individual profits (with respect to λ) becomes very similar to the slope of the profit function without screening (i.e. approximately linear). However, as the cost of external financing gets extremely low (in the neighborhood of $R^d = 0$), i.e. close to deposit rates of -100%, the diminishing returns to capital allow the bank to charge extreme risk premia and the benefit from screening becomes extremely large again. Thus, the expression in square brackets in the first line of equation (31) is always negative, strictly concave, and possesses a local maximum at intermediate levels of R^d.

The Extensive Margin The expression for the extensive margin is negative whenever $C^F > 0$ and monotonically increasing in R^d. In other words, as the deposit rate falls, the benefit from the ability to expand the portfolio to new customers by increasing λ^* continuously diminishes and reaches zero when the the gross deposit rate is zero. This is immediately apparent from the integral in the expression for the extensive margin. As λ^* decreases in R^d (Lemma 2) this expression approaches one as R^d tends to zero.

Thus, the combination of the expression for the intensive and extensive margin imply a strictly negative and concave relationship between the difference in profits $\Delta\pi(R^d)$ and the deposit rate.

The Screening Cost Since the cost of screening is simply a constant in equation (31) an increase in this cost will shift the concave relationship described before upward. Thus, if the cost of screening is sufficiently high, there must be two points at which the profits from screening coincide with the profits from the pooling contract.

Figure 3 shows that for reasonable assumptions there is an $\tilde{R}^d > 1$ such that $\pi^{NS} > \pi^S > 0$ for $R^d < \tilde{R}^d$ in a neighborhood of $\tilde{R}^d$.

Table 5: Logit Regressions for Predicting the Probability of Default

Dependent Variable: Insolvency within the next 3 years

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Accounting Ratios										
Liab./Assets	4.392***	3.697***	3.683***	3.405***	2.966***	3.280***	3.390***	3.545***	3.619***	3.697***
	(1.363)	(1.172)	(1.060)	(1.087)	(0.995)	(1.007)	(1.000)	(0.987)	(0.977)	(0.980)
Bank Liab./Assets	1.469	1.753	1.735*	1.472	1.701*	1.351	1.355*	1.306*	1.281*	1.275*
	(1.363)	(1.136)	(1.022)	(0.934)	(0.868)	(0.839)	(0.823)	(0.791)	(0.777)	(0.772)
Liab. Short/Assets	0.778	1.004	0.874	0.759	1.112	0.820	0.821	0.676	0.634	0.621
	(1.523)	(1.273)	(1.162)	(1.076)	(0.985)	(0.942)	(0.926)	(0.898)	(0.879)	(0.874)
Liq. Assets/Liab Short	0.051	0.038	0.053	0.048	0.079*	0.070	0.068	0.056	0.052	0.055
	(0.093)	(0.072)	(0.061)	(0.060)	(0.046)	(0.049)	(0.046)	(0.045)	(0.044)	(0.043)
Acc. Payab./Net Sales	1.988***	1.738***	2.136***	2.095***	2.084***	2.061***	2.058***	1.980***	2.015***	2.043***
	(0.569)	(0.551)	(0.487)	(0.433)	(0.385)	(0.372)	(0.354)	(0.348)	(0.340)	(0.336)
Gross Profit/Exp. Labor	-0.322**	-0.108	-0.139	-0.125	-0.126	-0.142	-0.155	-0.140	-0.149*	-0.150*
	(0.136)	(0.107)	(0.117)	(0.101)	(0.089)	(0.093)	(0.097)	(0.086)	(0.088)	(0.087)
Ord. Bus. Inc./Assets	-1.906	-3.091***	-3.015***	-3.023***	-3.113***	-3.090***	-2.997***	-2.943***	-2.883***	-2.790***
	(1.288)	(0.944)	(0.839)	(0.760)	(0.683)	(0.669)	(0.639)	(0.629)	(0.604)	(0.606)
Exp. Interest/Gross Debt	16.559***	14.346***	13.666***	14.596***	14.099***	14.583***	15.372***	14.936***	14.696***	14.359***
	(3.206)	(2.960)	(2.901)	(2.486)	(2.306)	(2.236)	(2.035)	(1.959)	(1.902)	(1.921)
Legal Form (relative to GmbH)										
AG	0.466	0.641*	0.620*	0.623*	0.534*	0.505	0.552*	0.609*	0.635**	0.618*
	(0.450)	(0.385)	(0.365)	(0.333)	(0.319)	(0.321)	(0.322)	(0.321)	(0.320)	(0.322)
KG	0.571*	0.485	0.520*	0.435	0.290	0.273	0.285	0.303	0.321	0.319
	(0.313)	(0.297)	(0.284)	(0.279)	(0.269)	(0.267)	(0.267)	(0.267)	(0.267)	(0.267)
Other	-0.040	-0.152	0.266	0.083	0.003	0.009	0.058	0.276	0.301	0.304
	(0.736)	(0.731)	(0.609)	(0.613)	(0.609)	(0.609)	(0.609)	(0.551)	(0.556)	(0.554)
Industry (relative to Manufacturing)										
Construction	-0.121	-0.110	-0.186	-0.223	-0.170	-0.254	-0.285	-0.286	-0.302	-0.314
	(0.553)	(0.528)	(0.527)	(0.513)	(0.442)	(0.441)	(0.435)	(0.429)	(0.427)	(0.427)
Wholesale & Trade	-0.509	-0.462	-0.234	-0.264	-0.386	-0.408	-0.414	-0.423	-0.434	-0.431
	(0.342)	(0.328)	(0.303)	(0.296)	(0.278)	(0.275)	(0.273)	(0.272)	(0.272)	(0.272)
Prof., Scient., & Tech.	0.108	-0.082	0.011	-0.141	-0.394	-0.518	-0.587	-0.721	-0.751*	-0.740*
	(0.487)	(0.476)	(0.429)	(0.421)	(0.417)	(0.424)	(0.427)	(0.445)	(0.441)	(0.438)
Admin. & Support	1.561*	1.518**	1.481**	1.306**	1.061*	0.902	0.812	0.672	0.630	0.642
	(0.821)	(0.621)	(0.625)	(0.619)	(0.596)	(0.587)	(0.584)	(0.590)	(0.585)	(0.582)
Other	0.035	0.064	0.067	0.040	-0.112	-0.174	-0.209	-0.254	-0.290	-0.287
	(0.339)	(0.307)	(0.299)	(0.285)	(0.274)	(0.272)	(0.271)	(0.270)	(0.271)	(0.271)
Transportation & Storage		-1.102	-1.185	-1.286	-1.504	-1.585	-1.631	-1.707*	-1.753*	-1.751*
		(1.029)	(1.030)	(1.027)	(1.019)	(1.020)	(1.019)	(1.021)	(1.021)	(1.021)
Age	-0.014	-0.011	-0.004	-0.025	-0.020	-0.025	-0.025	-0.025	-0.027	-0.029*
	(0.025)	(0.024)	(0.024)	(0.018)	(0.017)	(0.016)	(0.016)	(0.017)	(0.017)	(0.017)
Age^2	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-8.936***	-8.775***	-8.802***	-8.327***	-8.101***	-8.101***	-8.288***	-8.427***	-8.485***	-8.540***
	(0.937)	(0.897)	(0.846)	(0.796)	(0.715)	(0.717)	(0.724)	(0.726)	(0.731)	(0.737)
Obs.	15261	17692	19608	21794	24582	28027	32093	36294	40063	41380
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AUC Ex-Ante	0.757	0.756	0.774	0.768	0.756	0.832	0.797	0.873	.	.
AUC Ex-Post	0.806	0.809	0.809	0.818	0.823	0.828	0.834	0.838	0.841	0.842

Notes: The table reports the maximum likelihood estimates of coefficient vector γ in equation (34) based on logit models (35). Standard errors, reported in parentheses below each coefficient estimate, are corrected for serial correlation and clustered on firm. Coefficients that are significantly different from zero are indicated with *** for a p-value $p < 0.01$, ** for $p < 0.05$, and * for $p < 0.1$. The omitted legal form are limited liability companies (GmbH), AG stands for Aktiengesellschaft (equity firms), and KG refers to Kommanditgesellschaft (limited partnerships with at least one fully liable partner). The omitted industry is the manufacturing sector. Ex-ante AUC values for the years 2008 through 2009 could not be computed since we observe too few bankruptcies for those years within our sample of firms.

B An Empirical Measure of Banks' Loan-Portfolio Risk

We use borrowers' annual balance sheets and income statements to estimate a probability of default (PD) for each of the firms in our sample. We proxy the event of default, using the 533 bankruptcies observed within our unbalanced panel of 8,653 Austrian firms observed between 1993 and 2009. More precisely, we define

$$INS^h_{f,y} = \begin{cases} 1 & \text{if firm } f \text{ declares bankruptcy} \\ & \text{in any of the years } \tilde{y} \in \{y, y+1, ..., y+h\} \\ 0 & \text{otherwise,} \end{cases} \tag{33}$$

to indicate the event that a firm declares insolvency within h years from year y. Further, we construct

$$LO_{f,y} = \gamma_0 + \gamma_1' \cdot AR_{f,y} + \gamma_2' \cdot LF_{f,y} + \gamma_3' \cdot IND_{f,y} + \gamma_4' \cdot Z_{f,y}, \tag{34}$$

where $AR_{f,y}$ is a $k_1 \times 1$ vector of accounting ratios derived from firms' annual balance sheets and income statements, $LF_{f,y}$ is a $k_2 \times 1$ vector of dummies for the firm's legal form, $IND_{f,y}$ is a $k_3 \times 1$ vector of industry dummies, and $Z_{f,y}$ represents a $k_4 \times 1$ vector of additional firm specific characteristics including the firm's age. The vector $\gamma = (\gamma_0, \gamma_1', ..., \gamma_4')' \in \mathbb{R}^K$ is a vector of coefficients with $K = 1 + \sum_{i=1}^4 k_i$. The particular choice of accounting ratios in $AR_{f,y}$ is guided by results in Hayden's (2003) earlier work on predicting Austrian firms' PDs. Thus, based on the above definitions we estimate the logit models

$$p^h_{f,y^*} \equiv \Pr\left[\tilde{INS}^{h,y^*}_{f,y} = 1 \middle| AR_{f,y}, LF_{f,y}, IND_{f,y}, Z_{f,y}, y \leq y^*\right] = \frac{\exp(LO_{f,y})}{1 + \exp(LO_{f,y})}, \tag{35}$$

for the years $y^* \in \{2000, ..., 2009\}$, where

$$\tilde{INS}^{h,y^*}_{f,y} = \begin{cases} INS^h_{f,y} & \text{if firm } f \text{ declares bankruptcy before } y^* + 1 \\ \text{undefined} & \text{otherwise.} \end{cases}$$

This means that, for example, our estimates for the probability of firm f's default within h years from the year 2000, $\hat{p}^h_{f,2000}$, employ balance sheet information from 1993 up until 2000. The estimates for 2001 use data from 1993 through 2001, etc. Table 5 reports the estimates of the coefficient vector γ in equation (34) for each year between 2000 and 2009.

These estimates are not the particular focus of this study, yet they reveal information about the relative importance of the various firm specific characteristics' ability to predict bankruptcy. We find that, consistently across time periods, the relative magnitudes and signs of our coefficient estimates are consistent with the results found by Hayden (2003), who fits a similar model to a sample of Austrian firms between 1987 and 1997. In particular, our estimates indicate that the degree of leverage as well as activity ratios, such as the ratio of accounts payable to net sales, have a significantly positive impact on firms' default risk. On the other hand, the ratio of gross profits to expenditures on labor, measuring productivity, as well as ordinary business income as a fraction of assets, capturing firms' profitability, are significantly negatively related to the probability of default.

Most important for the purpose of this study, however, is the ability of these estimates to accurately predict the events of default and non-default. In order to assess the predictive ability of our estimates we employ the area under the receiver operating characteristic curve (AUC). Table 5 reports two versions of this statistic for each year. The AUC for in-sample (ex-post) predictions varies between 0.806 and 0.842 while our out-of-sample (ex-ante) predictions result in AUC values between 0.756 and 0.873. These numbers reveal that our predictions are fairly accurate, both in terms of ex-ante as well as ex-post predictions. As a reference, the average (across studies) AUC for standard prostate cancer screening tests (PSA) lies around 0.7. Hence, we use the coefficient estimates discussed above, together with logit models (35), in order to compute ex-ante probabilities of default for every firm, f, and year between 2000 and 2009, $\left\{\hat{p}^h_{f,y}\right\}_{y=2000}^{2009}$. We use these estimates to compute the empirical counterpart to equation (6).

C Full Regression Tables

Table 6: Full Regression Results ($\mu = 0.25$)

Dep. Var.: $\text{EDR}_{b,t}$	All Banks (1)	(2)	99% (3)	(4)	95% (5)	(6)
Constant	0.562***	1.598**	0.562***	1.633**	0.564***	1.718**
	(0.0239)	(0.680)	(0.0243)	(0.692)	(0.0254)	(0.728)
MP_t	-0.0259	-0.0722***	-0.0268	-0.0730***	-0.0317	-0.0754***
	(0.0245)	(0.0264)	(0.0249)	(0.0268)	(0.0261)	(0.0281)
$GAP_t^{\text{tr},25}$	-0.124***	-0.0710	-0.124***	-0.0708	-0.125***	-0.0761
	(0.0252)	(0.0513)	(0.0256)	(0.0521)	(0.0268)	(0.0547)
$DD^{\text{tr},25}$	0.208***	0.157***	0.211***	0.159***	0.219***	0.170***
	(0.0376)	(0.0531)	(0.0381)	(0.0540)	(0.0399)	(0.0565)
Bank: Capitalization (1-5)						
Cap. 2		0.0174		0.0178		0.0156
		(0.0386)		(0.0398)		(0.0439)
Cap. 3		-0.0283		-0.0281		-0.0284
		(0.0472)		(0.0483)		(0.0514)
Cap. 4		0.000753		-0.000844		-0.00496
		(0.0552)		(0.0561)		(0.0585)
Cap. 5		-0.349		-0.351		-0.359
		(0.251)		(0.252)		(0.252)
Bank: Cash Ratio (1-3)						
Cash Rat. 2		-0.00113		0.000137		0.00199
		(0.0425)		(0.0428)		(0.0437)
Cash Rat. 3		0.00857		0.0106		0.0147
		(0.0590)		(0.0592)		(0.0596)
Bank: Size by Assets (1-3)						
Size 2		0.0167		0.0156		0.0117
		(0.0618)		(0.0620)		(0.0623)
Size 3		-0.0179		-0.0206		-0.00580
		(0.0805)		(0.0810)		(0.0886)
Aggregate Characteristics						
$y_q^{AT} - \bar{y}_q^{AT}$		-0.0714**		-0.0717**		-0.0702**
		(0.0311)		(0.0316)		(0.0331)
π_q^{AT}		0.0423*		0.0420*		0.0405*
		(0.0225)		(0.0229)		(0.0240)
$i_q^{10,AT} - i_q^{3,EA}$		0.00986		0.00982		0.0101
		(0.0315)		(0.0320)		(0.0338)
$i_q^{10,AT} - i_q^{10,EA}$		0.239		0.226		0.195
		(0.260)		(0.265)		(0.280)
AT Bank-Loans/Total Assets		-0.00962		-0.0103		-0.0120
		(0.0115)		(0.0118)		(0.0124)
AT Bank-Loan Growth		0.00565		0.00600		0.00685
		(0.00411)		(0.00418)		(0.00438)
GKE Credit/AT Bank-Loans		-1.787*		-1.808*		-1.857*
		(0.991)		(1.007)		(1.055)
Bank FEs	no	yes	no	yes	no	yes
No. Banks	316	316	312	312	300	300
Obs.	15827	15827	15587	15587	14867	14867
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
Mean EDF	0.525	0.525	0.526	0.526	0.527	0.527
D-in-D/Mean EDF	0.397	0.300	0.401	0.303	0.416	0.322

Notes: The table reports coefficient estimates for various specifications of regression model (11). Standard errors are clustered on bank and reported in parentheses underneath the coefficient. Significance levels are indicated by * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

Table 7: Full Regression Results ($\mu = 0.15$)

Dep. Var.: $\mathrm{EDR}_{b,t}$	All Banks (1)	(2)	99% (3)	(4)	95% (5)	(6)
Constant	0.551***	1.147**	0.551***	1.179**	0.553***	1.270**
	(0.0224)	(0.561)	(0.0228)	(0.571)	(0.0238)	(0.604)
MP_t	0.00524	-0.0363	0.00460	-0.0366	0.000980	-0.0387
	(0.0332)	(0.0272)	(0.0337)	(0.0276)	(0.0353)	(0.0290)
$GAP_t^{\mathrm{tr},15}$	-0.0812***	-0.0718***	-0.0809***	-0.0718***	-0.0824***	-0.0741***
	(0.0207)	(0.0195)	(0.0210)	(0.0199)	(0.0220)	(0.0209)
$DD^{\mathrm{tr},15}$	0.145***	0.171***	0.147***	0.173***	0.155***	0.180***
	(0.0311)	(0.0261)	(0.0316)	(0.0265)	(0.0330)	(0.0278)
Bank: Capitalization (1-5)						
Cap. 2		0.00439		0.00426		0.00446
		(0.0393)		(0.0404)		(0.0448)
Cap. 3		-0.0432		-0.0434		-0.0418
		(0.0484)		(0.0494)		(0.0528)
Cap. 4		-0.0122		-0.0137		-0.0153
		(0.0611)		(0.0619)		(0.0643)
Cap. 5		-0.370		-0.373		-0.378*
		(0.227)		(0.227)		(0.228)
Bank: Cash Ratio (1-3)						
Cash Rat. 2		-0.0214		-0.0206		-0.0203
		(0.0387)		(0.0390)		(0.0400)
Cash Rat. 3		-0.0229		-0.0217		-0.0196
		(0.0536)		(0.0538)		(0.0542)
Bank: Size by Assets (1-3)						
Size 2		0.00874		0.00784		0.00452
		(0.0659)		(0.0659)		(0.0660)
Size 3		-0.00656		-0.00848		0.0281
		(0.0826)		(0.0829)		(0.0914)
Aggregate Characteristics						
$y_q^{AT} - \bar{y}_q^{AT}$		-0.0292**		-0.0295**		-0.0294**
		(0.0135)		(0.0138)		(0.0145)
π_q^{AT}		-0.00981		-0.0100		-0.0113
		(0.0144)		(0.0146)		(0.0154)
$i_q^{10,AT} - i_q^{3,EA}$		0.00925		0.00902		0.00926
		(0.0187)		(0.0190)		(0.0200)
$i_q^{10,AT} - i_q^{10,EA}$		0.123		0.116		0.0942
		(0.175)		(0.178)		(0.188)
AT Bank-Loans/Total Assets		-0.00457		-0.00516		-0.00693
		(0.0105)		(0.0107)		(0.0113)
AT Bank-Loan Growth		0.00278		0.00305		0.00375
		(0.00361)		(0.00368)		(0.00387)
GKE Credit/AT Bank-Loans		-0.885		-0.905		-0.961
		(0.611)		(0.622)		(0.654)
Bank FEs	no	yes	no	yes	no	yes
No. Banks	316	316	312	312	300	300
Obs.	20305	20305	19993	19993	19057	19057
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
Mean EDF	0.525	0.525	0.526	0.526	0.527	0.527
D-in-D/Mean EDF	0.277	0.327	0.280	0.329	0.294	0.341

Notes: The table reports coefficient estimates for various specifications of regression model (11). Standard errors are clustered on bank and reported in parentheses underneath the coefficient. Significance levels are indicated by * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

Table 8: Full Regression Results ($\mu = 0.20$)

Dep. Var.: $\text{EDR}_{b,t}$	All Banks (1)	All Banks (2)	99% (3)	99% (4)	95% (5)	95% (6)
Constant	0.562***	1.191**	0.562***	1.226**	0.564***	1.326**
	(0.0239)	(0.587)	(0.0243)	(0.598)	(0.0254)	(0.632)
MP_t	-0.00551	-0.0279	-0.00609	-0.0282	-0.00980	-0.0298
	(0.0332)	(0.0246)	(0.0337)	(0.0250)	(0.0353)	(0.0263)
$GAP_t^{\text{tr},20}$	-0.0990***	-0.126***	-0.0987***	-0.126***	-0.100***	-0.130***
	(0.0237)	(0.0428)	(0.0241)	(0.0435)	(0.0252)	(0.0458)
$DD^{\text{tr},20}$	0.163***	0.212***	0.165***	0.214***	0.172***	0.222***
	(0.0329)	(0.0411)	(0.0334)	(0.0418)	(0.0349)	(0.0440)
Bank: Capitalization (1-5)						
Cap. 2		0.00755		0.00765		0.00684
		(0.0379)		(0.0389)		(0.0430)
Cap. 3		-0.0454		-0.0454		-0.0449
		(0.0467)		(0.0477)		(0.0508)
Cap. 4		-0.00575		-0.00735		-0.0100
		(0.0603)		(0.0611)		(0.0633)
Cap. 5		-0.399		-0.402		-0.409
		(0.253)		(0.253)		(0.253)
Bank: Cash Ratio (1-3)						
Cash Rat. 2		-0.0122		-0.0112		-0.0104
		(0.0387)		(0.0390)		(0.0399)
Cash Rat. 3		-0.0130		-0.0115		-0.00887
		(0.0550)		(0.0552)		(0.0555)
Bank: Size by Assets (1-3)						
Size 2		0.00348		0.00246		-0.00110
		(0.0622)		(0.0622)		(0.0624)
Size 3		-0.0229		-0.0251		0.00328
		(0.0798)		(0.0802)		(0.0897)
Aggregate Characteristics						
$y_q^{AT} - \bar{y}_q^{AT}$		-0.0320***		-0.0324***		-0.0324**
		(0.0117)		(0.0119)		(0.0125)
π_q^{AT}		0.0101		0.00981		0.00880
		(0.0219)		(0.0222)		(0.0233)
$i_q^{10,AT} - i_q^{3,EA}$		-0.00722		-0.00756		-0.00831
		(0.0201)		(0.0205)		(0.0217)
$i_q^{10,AT} - i_q^{10,EA}$		0.359		0.351		0.336
		(0.220)		(0.224)		(0.235)
AT Bank-Loans/Total Assets		-0.00146		-0.00213		-0.00386
		(0.0104)		(0.0106)		(0.0112)
AT Bank-Loan Growth		0.00172		0.00200		0.00262
		(0.00335)		(0.00341)		(0.00359)
GKE Credit/AT Bank-Loans		-1.261**		-1.284**		-1.360**
		(0.640)		(0.651)		(0.685)
Bank FEs	no	yes	no	yes	no	yes
No. Banks	316	316	312	312	300	300
Obs.	18015	18015	17739	17739	16911	16911
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
Mean EDF	0.525	0.525	0.526	0.526	0.527	0.527
D-in-D/Mean EDF	0.311	0.404	0.314	0.406	0.327	0.421

Notes: The table reports coefficient estimates for various specifications of regression model (11). Standard errors are clustered on bank and reported in parentheses underneath the coefficient. Significance levels are indicated by * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

Table 9: Full Regression Results ($\mu = 0.30$)

	All Banks		99%		95%	
Dep. Var.: $\mathrm{EDR}_{b,t}$	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.550***	1.201**	0.550***	1.218**	0.551***	1.270**
	(0.0250)	(0.537)	(0.0254)	(0.546)	(0.0265)	(0.574)
MP_t	-0.0140	-0.0506*	-0.0146	-0.0508*	-0.0187	-0.0522
	(0.0250)	(0.0298)	(0.0254)	(0.0303)	(0.0266)	(0.0317)
$GAP_t^{\mathrm{tr},30}$	-0.112***	-0.107**	-0.112***	-0.109**	-0.112***	-0.117**
	(0.0262)	(0.0452)	(0.0266)	(0.0460)	(0.0279)	(0.0484)
$DD^{\mathrm{tr},30}$	0.201***	0.235***	0.203***	0.241***	0.212***	0.258***
	(0.0364)	(0.0480)	(0.0370)	(0.0489)	(0.0387)	(0.0513)
Bank: Capitalization (1-5)						
Cap. 2		0.00802		0.00794		0.00520
		(0.0398)		(0.0409)		(0.0449)
Cap. 3		-0.0297		-0.0300		-0.0301
		(0.0476)		(0.0487)		(0.0517)
Cap. 4		-0.0388		-0.0414		-0.0476
		(0.0536)		(0.0547)		(0.0572)
Cap. 5		-0.311		-0.315		-0.326
		(0.200)		(0.201)		(0.202)
Bank: Cash Ratio (1-3)						
Cash Rat. 2		0.00608		0.00768		0.00983
		(0.0413)		(0.0417)		(0.0425)
Cash Rat. 3		0.0276		0.0301		0.0349
		(0.0564)		(0.0566)		(0.0572)
Bank: Size by Assets (1-3)						
Size 2		0.0204		0.0190		0.0144
		(0.0639)		(0.0640)		(0.0644)
Size 3		-0.0275		-0.0306		-0.0221
		(0.0823)		(0.0828)		(0.0900)
Aggregate Characteristics						
$y_q^{AT} - \bar{y}_q^{AT}$		-0.0279		-0.0262		-0.0205
		(0.0209)		(0.0213)		(0.0223)
π_q^{AT}		0.0104		0.00883		0.00470
		(0.0267)		(0.0271)		(0.0284)
$i_q^{10,AT} - i_q^{3,EA}$		0.0107		0.0111		0.0125
		(0.0253)		(0.0258)		(0.0271)
$i_q^{10,AT} - i_q^{10,EA}$		0.299		0.286		0.253
		(0.261)		(0.266)		(0.282)
AT Bank-Loans/Total Assets		-0.00772		-0.00838		-0.0100
		(0.0116)		(0.0118)		(0.0125)
AT Bank-Loan Growth		0.00132		0.00156		0.00224
		(0.00444)		(0.00451)		(0.00473)
GKE Credit/AT Bank-Loans		-0.896		-0.876		-0.839
		(0.651)		(0.662)		(0.694)
Bank FEs	no	yes	no	yes	no	yes
No. Banks	316	316	312	312	300	300
Obs.	14215	14215	13999	13999	13351	13351
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
Mean EDF	0.525	0.525	0.526	0.526	0.527	0.527
D-in-D/Mean EDF	0.383	0.448	0.387	0.458	0.402	0.490

Notes: The table reports coefficient estimates for various specifications of regression model (11). Standard errors are clustered on bank and reported in parentheses underneath the coefficient. Significance levels are indicated by * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

D Relation Between Equation (10) and Equation (11)

For any given set of individual bank and aggregate characteristics characteristics, $X_{b,t}$, regression model (11) directly implies the following conditional expectations:

$$\begin{aligned}
\mathrm{E}\left[EDR_{b,t}\,|TRG_t^{\mu}=1, MPR_t=0, X_{b,t}\right] &= \alpha_0^{\mu}+\alpha_2^{\mu}+\beta^{\mu\prime}X_{b,t} \\
\mathrm{E}\left[EDR_{b,t}\,|TRG_t^{\mu}=0, MPR_t=0, X_{b,t}\right] &= \alpha_0^{\mu}+\beta^{\mu\prime}X_{b,t} \\
\mathrm{E}\left[EDR_{b,t}\,|TRG_t^{\mu}=1, MPR_t=1, X_{b,t}\right] &= \alpha_0^{\mu}+\alpha_1^{\mu}+\alpha_2^{\mu}+DD^{\mu}+\beta^{\mu\prime}X_{b,t} \\
\mathrm{E}\left[EDR_{b,t}\,|TRG_t^{\mu}=0, MPR_t=1, X_{b,t}\right] &= \alpha_0^{\mu}+\alpha_1^{\mu}+\beta^{\mu\prime}X_{b,t}.
\end{aligned}$$

Therefore, given regression model (11), the differences defined in equation (9) can be written as

$$\begin{aligned}
\left.\frac{\Delta EDR}{\Delta TRG^{\mu}}\right|_{MPR_t=1,X_{b,t}} &= \alpha_2^{\mu} \\
\left.\frac{\Delta EDR}{\Delta TRG^{\mu}}\right|_{MPR_t=0,X_{b,t}} &= \alpha_2^{\mu}+DD^{\mu},
\end{aligned}$$

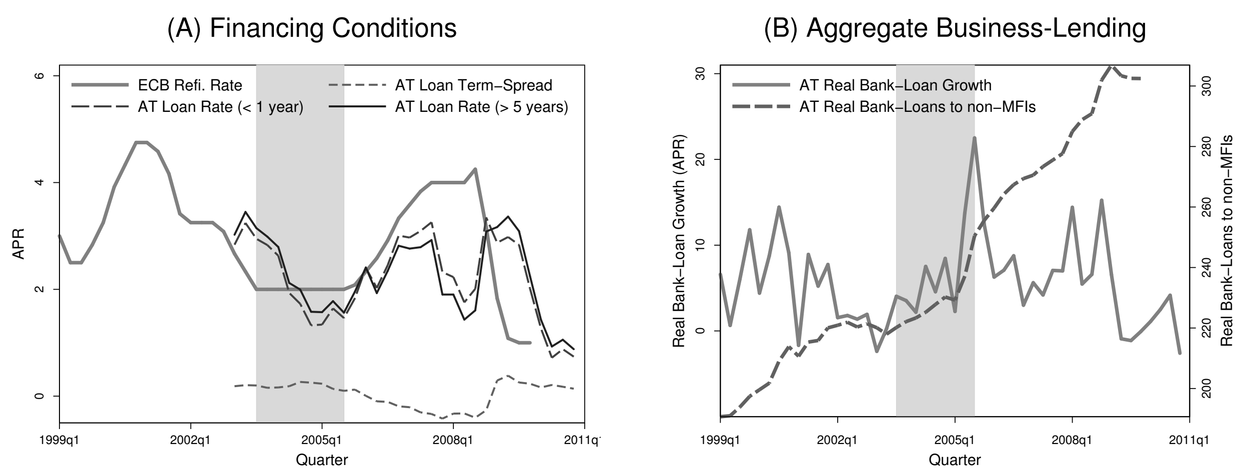
which directly imply the definition in equation (10). Note further that the third conditioning argument in all the above expectations, $X_{b,t}$, is irrelevant if $\beta^{\mu\prime}=0$.

E The Most Recent Business-Lending Cycle in Austria

In order to facilitate the international comparability of our findings we briefly discuss the most recent business-lending cycle in Austria and point out several important observations.

First, panel (A) of Figure 7 illustrates a significant decrease in real interest rates on debt of different maturity throughout the period of low and stable policy interest rates between 2003 and 2005. Looking at panel (B) of Figure 7, one can observe that this significant drop in real interest rates goes hand in hand with a significant increase in business-lending throughout the same period. These two tendencies point toward traditional interest rate channels as well as the "broad credit channel" (Bernanke & Gertler 1995) of monetary policy.

Figure 7: The Most Recent Business-Lending Cycle in Austria (2000 - 2010)

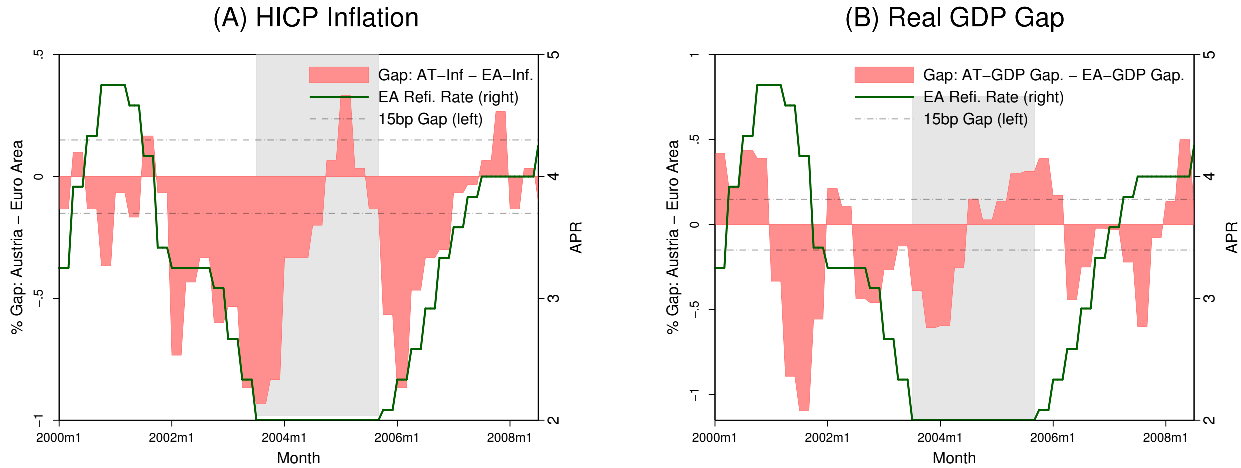


Notes: Panel (A) illustrates nominal interest rates on the ECB's main refinancing facility as well as real interest rates for Austrian (AT) bank-credit of different maturity. Real rates are computed by subtracting AT HICP inflation. Further, we report the term-spread between loan rates for the two reported maturities. Panel (B) depicts levels and annualized quarterly growth rates of Austrian real bank-lending to non monetary and financial institutions (non-MFIs). A real series is constructed by dividing nominal bank-lending (in billions of Euros) by the AT GDP deflator (2005q1=100). All data are drawn from the ECB's statistical data warehouse (http://sdw.ecb.europa.eu). The gray areas indicate the period during which ECB refinancing rates were kept at 2%.

Second, Figure 7 further hints at a channel recently emphasized by Woodford (2010). He argues that a strong amplification mechanism in the transmission of monetary policy is triggered whenever the spread between long-term and short-term interest rates decreases. This is motivated by the fact that investment decisions—and hence real activity—generally depend mostly on long-term rather than short-term financing conditions. One can see that the biggest spike in business-lending growth, during 2005, precisely coincides with the onset of a decline in the spread between loans of maturity greater than 5 years and loans with maturity less than 1 year.

Furthermore, it appears that these mechanisms were also likely to be at work at the end of 2007, in mid 2008, as well as in the year 2010. Thus, we argue that these channels are important features of the monetary transmission mechanism but do not seem to be phenomena that are restricted to periods of extremely low and stable policy interest rates.

Figure 8: Economic Activity: Austria vs. Euro Area



Notes: The figure displays the gap between a HICP inflation as well as the real output gap for Austria (AT) and the Euro Area (EA).

F Alternative Measures of Economic Activity

Figure 8 illustrates the main thought experiment based on two alternative measures of economic activity: HICP inflation, and the real output gap. Since these two measures do not have a natural interpretation in terms of interest rates, it is not obvious what an appropriate value for μ is. Choosing $\mu = 0.15$ delivers a thought experiment that is very similar to our main specification. In fact, when using these two measures, the main regression results are qualitatively equivalent to those in our main specification. Table 10 illustrates this result. Notice that the effects are stronger for inflation, which is consistent the fact that the ECB almost exclusively cares about inflation when trying to stabilize the euro area. Nevertheless, we still see significant results if we consider the difference in real GDP gaps only.

G Alternative Taylor Rule Measures

Inspired by Taylor (1993) we construct various weighted averages of inflation and output gaps, that have the dual interpretation of predicting nominal policy rates:

$$i_q^{j,TR} = \bar{r}_q^j + \bar{\pi}_q^j + (1+\phi_\pi)(\pi_q^j - \bar{\pi}_q^j) + \phi_y(y_q^j - \bar{y}_q^j) + \phi_i(i_q^{ECB} - i_{q-1}^{ECB}). \tag{36}$$

Table 10: Alternative Measures of Economic Activity ($\mu = 0.15$)

	All Banks		99%		95%	
Dependent Variable: $\text{EDR}_{b,t}$	(1)	(2)	(3)	(4)	(5)	(6)
Economic Activity: Taylor Rule						
Constant	0.551***	1.147**	0.551***	1.179**	0.553***	1.270**
	(0.0224)	(0.561)	(0.0228)	(0.571)	(0.0238)	(0.604)
MP_t	0.00524	-0.0363	0.00460	-0.0366	0.000980	-0.0387
	(0.0332)	(0.0272)	(0.0337)	(0.0276)	(0.0353)	(0.0290)
$GAP_t^{\text{tr},15}$	-0.0812***	-0.0718***	-0.0809***	-0.0718***	-0.0824***	-0.0741***
	(0.0207)	(0.0195)	(0.0210)	(0.0199)	(0.0220)	(0.0209)
$DD^{\text{tr},15}$	0.145***	0.171***	0.147***	0.173***	0.155***	0.180***
	(0.0311)	(0.0261)	(0.0316)	(0.0265)	(0.0330)	(0.0278)
No. Banks	316	316	312	312	300	300
Obs.	20305	20305	19993	19993	19057	19057
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
$\overline{EDR}_T$	0.525	0.525	0.526	0.526	0.527	0.527
$DD^{\text{tr},15}/\overline{EDR}_T$	0.277	0.327	0.280	0.329	0.294	0.341
Economic Activity: GDP Gap						
Constant	0.516***	0.245	0.516***	0.261	0.516***	0.294
	(0.0229)	(0.380)	(0.0232)	(0.387)	(0.0243)	(0.408)
MP_t	0.0505	-0.0306	0.0501	-0.0305	0.0481	-0.0326
	(0.0422)	(0.0452)	(0.0429)	(0.0459)	(0.0449)	(0.0483)
$GAP_t^{\text{gdp},15}$	-0.00468	0.0519***	-0.00417	0.0525***	-0.00244	0.0551***
	(0.0168)	(0.0148)	(0.0171)	(0.0150)	(0.0179)	(0.0158)
$DD^{\text{gdp},15}$	0.0604**	0.0459*	0.0619**	0.0463*	0.0657**	0.0476*
	(0.0297)	(0.0246)	(0.0302)	(0.0250)	(0.0315)	(0.0262)
No. Banks	316	316	312	312	300	300
Obs.	20111	20111	19799	19799	18863	18863
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
$\overline{EDR}_T$	0.525	0.525	0.526	0.526	0.527	0.527
$DD^{\text{tr},15}/\overline{EDR}_T$	0.115	0.087	0.118	0.088	0.125	0.090
Economic Activity: Inflation						
Constant	0.555***	0.473	0.556***	0.497	0.557***	0.554
	(0.0232)	(0.500)	(0.0236)	(0.510)	(0.0247)	(0.540)
MP_t	0.0178	-0.0553	0.0177	-0.0547	0.0155	-0.0552
	(0.0455)	(0.0520)	(0.0462)	(0.0528)	(0.0484)	(0.0556)
$GAP_t^{\text{inf},15}$	-0.103***	-0.0440*	-0.103***	-0.0451*	-0.105***	-0.0491*
	(0.0198)	(0.0258)	(0.0201)	(0.0262)	(0.0211)	(0.0276)
$DD^{\text{inf},15}$	0.151***	0.154**	0.153***	0.157**	0.159***	0.164**
	(0.0562)	(0.0649)	(0.0570)	(0.0661)	(0.0597)	(0.0698)
No. Banks	313	313	309	309	297	297
Obs.	16550	16550	16298	16298	15542	15542
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
$\overline{EDR}_T$	0.525	0.525	0.526	0.526	0.527	0.527
$DD^{\text{tr},15}/\overline{EDR}_T$	0.288	0.293	0.291	0.298	0.303	0.312
Bank FEs	no	yes	no	yes	no	yes
Controls	no	yes	no	yes	no	yes

Notes: Standard errors are clustered on bank and reported in parentheses underneath the coefficients. Significance levels are indicated by * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

where i_q^{ECB} is the ECB refinancing rate, π_q^j and y_q^j represents HICP inflation and real GDP in region $j \in \{AT, EA\}$ in quarter q, respectively. $\bar{r}_q^j$, $\bar{y}_q^j$, and $\bar{\pi}_q^j$ denote equilibrium (or *target*) levels of real interest rates, real GDP, and inflation in regions j, respectively. Finally, ϕ_π, ϕ_y, and ϕ_i represent policy weights on inflation stabilization, output stabilization, and interest rate smoothing, respectively.

We consider six alternative specifications for each region in order to identify periods during which ECB monetary policy was likely to be exogenous to the Austrian economy. For each of these specifications we use Taylor's original suggestion of equal weights on on output and inflation stabilization, i.e. $\phi_\pi = \phi_y = 0.5$. Further, we approximate the equilibrium real interest rate as well as the natural level for each region j using the Hodrick-Prescott filter with a smoothing parameter of $\lambda = 1600$, i.e. $\bar{r}_q^j = \hat{\bar{r}}_q^{j,HP}$ and $\bar{y}_q^j = \hat{\bar{y}}_q^{j,HP}$. For the remaining parameters we choose the following six alternative specifications:

(A.1) We proxy the target inflation with average HICP inflation in Austria and the euro area, $\bar{\pi}_q^{AT} = 2.23125$ and $\bar{\pi}_q^{EA} = 2.6086905$, taken over the pre EMU period 1991-1998. Further, we assume the ECB does not care about interest rate smoothing, i.e. $\phi_i = 0$

(A.2) $\bar{\pi}_q^{AT} = 2.23125$, $\bar{\pi}_q^{EA} = 2.6086905$, and $\phi_i = 0.9$

(B.1) We set target inflation to 2%, i.e. $\bar{\pi}_q^{AT} = \bar{\pi}_q^{EA} = 2$, and $\phi_i = 0$

(B.2) $\bar{\pi}_q^{AT} = \bar{\pi}_q^{EA} = 2$, and $\phi_i = 0.9$

(C.1) We proxy equilibrium inflation in each region with an HP trend, i.e. $\bar{\pi}_q^j = \hat{\bar{r}}_q^{j,HP}$, and $\phi_i = 0$

(C.2) $\bar{\pi}_q^j = \hat{\bar{r}}_q^{j,HP}$, and $\phi_i = 0.9$

The alternative specifications highlight several important phenomena. First, Taylor's basic specification of $\phi_\pi = \phi_y = 0.5$ does fairly well in predicting ECB refinancing rates between 1999 and 2008. Second, interest smoothing motives, i.e. specifications with $\phi_i > 0$, do not seem to play a significant role for the purpose of our thought experiment. Finally, and most importanty for our analysis, the difference between the predictions for Austria and the euro area, $i_q^{AT,TR} - i_q^{EA,TR}$, is very robust across specifications.

Figure 9: Alternative Taylor Rule Specifications