Uncertainty and the Cost of Bank vs. Bond Finance

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Abstract

How does heightened uncertainty affect the costs of raising finance through the bond market and through bank loans? Empirically, I find that a rise in uncertainty is accompanied by an increase in corporate bond yields and a decrease in bank lending rates. This new stylized fact can be explained in a model with costly state verification and a special informational role for banks. In contrast to bond investors, banks acquire additional costly information about borrowers in times of uncertainty in order to reduce uncertainty. Having this information, the lending relationship becomes more valuable to the bank, resulting in a lower lending rate so that the relationship is not put at risk. The cost of bond finance increases because bond investors demand to be compensated for the increased risk of firm default. These findings suggest that the adverse effects of uncertainty are mitigated for firms that rely on bank finance as long as banks are highly capitalized.

JEL-Classification: E32, E43, E44, G21

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1 Introduction

Is the cost of bank finance different from that of bond finance in times of elevated uncertainty? In contrast to bond holders, banks often form long-term relationships with their borrowers. Maintaining these relationships induces banks to lend at more favorable terms in response to changes in a firm's credit risk (see, e.g., Berlin and Mester, 1999; Petersen and Rajan, 1995). Sharpe (1991) argues that banks may continue to lend to troubled borrowers even at concessionary rates. Therefore, the costs of bond finance and bank loans may evolve differently during periods of heightened uncertainty.

This paper makes two contributions. First, using uncertainty proxies calculated from survey data, I document a new stylized fact for the United States and Germany: following a sudden hike in uncertainty, the cost of corporate bond finance increases, whereas bank loan rates decrease. Second, using a simple partial equilibrium model, I explore the reasons for these opposite reactions of bond finance and bank loans. The model features costly state verification and a special informational role for banks. In contrast to bond holders, banks maintain long-term relationships with their clients and are able to acquire costly information about borrowers. When uncertainty increases, banks collect additional information which reduces uncertainty and the expected borrower default. In addition, this information makes the relationship even more valuable by strengthening the banks' information monopoly over the borrower in the future. Banks reduce lending rates so that the relationship is not jeopardized.

A recent strand of the literature argues that uncertainty affects the real economy through financial frictions. Gilchrist, Sim, and Zakrajšek (2014) and Christiano, Motto, and Rostagno (2014) suggest that higher uncertainty about idiosyncratic productivity increases the probability of firm default. Due to limited liability, the risk premium on the cost of external financing rises (*risk compensation channel*).[1] Gilchrist et al. (2014) provide empirical evidence for this channel for the United States using spreads derived from corporate bond yields.[2] However, many firms, particularly in the Euro Area, rely more heavily on banks for debt financing than on the capital market.[3]

[1]The interaction between uncertainty and different types of financial frictions is also theoretically analyzed by Arellano, Bai, and Kehoe (2016), Bonciani and van Roye (2016), Cesa-Bianchi and Fernandez-Corugedo (2014), Chugh (2016), Dorofeenko, Lee, and Salyer (2008), Fendoglu (2014), Fernández-Villaverde (2010), Güntner (2015), and Hafstead and Smith (2012).

[2]For the United States, Popp and Zhang (2016) confirm that a rise in uncertainty widens the corporate bond spread. In addition, Caldara, Fuentes-Albero, Gilchrist, and Zakrajšek (2016) show that increases in uncertainty deteriorate financial conditions as measured by the excess bond premium. For Germany, Popescu and Smets (2010) demonstrate that higher uncertainty raises the common component of several risk premium indices.

[3]Figure 1 presents the shares of total debt of nonfinancial corporations for a number of European countries and the United States in 2015. For Spain, Germany, and Italy, corporate bonds account for 2–13% of their total debt, for France and the United Kingdom, this figure is 22–26%, whereas for the United States it is 71%.

The novel contribution of this paper is to analyze the effects of uncertainty on corporate bond yields and bank loan rates for the United States and Germany. To construct idiosyncratic uncertainty measures, I follow the strategy of Bachmann, Elstner, and Sims (2013) and use survey data from the Philadelphia Fed's Business Outlook Survey (BOS) for the United States and from the IFO Business Climate Survey (IFO-BCS) for Germany. This is in contrast to Gilchrist et al. (2014), who rely on U.S. financial data.[4] The drawback of financial data is that they limit the analysis to large firms, whereas survey data encompass firms of all sizes–at least in the IFO-BCS. Furthermore, survey data capture actual decision-makers at the firms in contrast to, for example, financial analysts (Bachmann et al., 2013). From the survey data, I calculate the cross-sectional dispersion of expectations about future economic activity for each country and use it as a proxy for idiosyncratic uncertainty. Using vector autoregression models, a sudden rise in uncertainty leads to an increase in corporate bond yields, whereas bank loan rates fall. This contrasting behavior is found for both the United States and Germany. A number of robustness checks confirm this result.

Why do the costs of bank finance decrease in periods of heightened uncertainty while those of bond finance increase? To answer this question, I develop a partial equilibrium model that features costly state verification (CSV) and a special informational role for banks. Firms finance their projects by obtaining bank loans or issuing bonds. There are two types of informational problems: (i) information is asymmetrically distributed between borrowers and lenders, and (ii) the outcome of a firm's project is ex-ante uncertain to both the borrower and the lender. Uncertainty about the project stems both from risk and ambiguity (Knightian uncertainty) (Rossi, Sekhposyan, and Soupre, 2016). An increase in risk raises the dispersion of the distribution. Higher ambiguity makes it harder to correctly assign probabilities to each possible event.

In contrast to bond investors, banks are able to at least partially overcome both types of informational problems. First, through continuous interactions with the customers, banks acquire private information and reduce informational asymmetries over time (see, e.g., Boot, 2000). Banks obtain an informational advantage over other, uninformed lenders, and they can charge a markup on the loan rate in later periods due to monopoly power (see, e.g., Greenbaum, Kanatas, and Venezia, 1989; Rajan, 1992; Sharpe, 1990). This is the

In contrast, bank loans amount to 29% of firm debt in the United States and 74–98% in the five European countries.

[4] To derive a measure for idiosyncratic uncertainty, Gilchrist et al. (2014) use daily stock returns for U.S. nonfinancial corporations. In a first step, they remove the forecastable variation in idiosyncratic excess returns. In a second step, they compute the quarterly firm-level standard deviation of the estimated residuals from the first step. In a third step, they assume that this standard deviation follows an AR(1) process with firm fixed effects, a firm-specific term and time fixed effects. The series of time fixed effects is used as an aggregate proxy for idiosyncratic uncertainty.

long-term-benefit of collecting private information. Second, banks can spend resources to collect additional market information in order to reduce the ambiguous component of the project's return distribution and share this information with their borrower.[5] This is the short-term benefit of acquiring market information. This additional market information encompasses more than what is publicly available, and can include, for example, information about the market in which the firm operates gleaned from talking to other customers active in the same sector or by having the bank's economic department conduct in-depth market analyses. Market information does not affect the risky component of the return distribution, however. As with private information, market information facilitates the lender's continuation or liquidation of the project in the event of borrower default. A future default becomes less costly and banks can charge higher loan rates in later periods. This is the long-term-benefit of collecting market information.

Banks can counteract an increase in uncertainty by collecting additional costly market information that (i) reduces the ambiguous component and dampens the increase in uncertainty. Subsequently, the increase in the expected probability of borrower default and in the lending rate is attenuated. As a side effect, additional market information (ii) increases the value of the customer-bank relationship via higher future markups due to lower costs of borrower default. The bank's incentive to prevent the borrower from defaulting during the period of elevated uncertainty becomes stronger, and thus the bank lowers the lending rate during this time. Put together, the two effects constitute the *information channel* of uncertainty. This channel puts downward pressure on the lending rate in times of heightened uncertainty.

The bank loan rate is determined by both the risk compensation and the information channel. If the sum of the short-term advantage of lower uncertainty and the long-term benefit of continuing the relationship are larger than the short-term gain of being adequately compensated for the increased risk, banks lower the lending rate. In contrast, bond investors have only publicly available information and are not specialized in collecting private or additional market information (see, e.g. Rajan, 1992). When uncertainty rises, the cost of corporate bonds is determined only by the risk compensation channel, and market debt becomes more expensive.

A different explanation for why average bank lending rates fall could have to do with compositional changes among borrowers (see, e.g., Gilchrist and Mojon, forthcoming). Following a rise in uncertainty, banks may prefer to lend less to risky borrowers and increase the amount of loans to firms with relatively safe projects. The cost of relatively safe loans should remain unaffected by higher uncertainty. Risky loans, if they are even granted, are

[5] In the same spirit, De Fiore and Uhlig (2011) argue that banks can acquire additional information about an economy-wide uncertain productivity factor and adjust the loan contract accordingly, which reduces the riskiness of bank finance for a firm compared to bond finance.

offered at higher rates to compensate the lender. A higher fraction of safe loans and a lower fraction of risky loans could yield a lower average lending rate. To analyze this channel, one of the empirical robustness checks looks at loan rates for different risk categories. In response to a rise in uncertainty, the lending rate always falls, regardless of the riskiness of the borrower. Even relatively high-risk borrowers are charged lower lending rates when uncertainty increases. While banks may still change the composition of their portfolios in periods of elevated uncertainty, risk shifting cannot explain why lending rates fall for all risk types.[6]

This paper is the first to analyze the link between (idiosyncratic) uncertainty and the costs of bank loans. There are several contributions in the literature that look at the effects of (aggregate) uncertainty on the supply of bank loans (Alessandri and Bottero, 2017; Bordo, Duca, and Koch, 2016; Buch, Buchholz, and Tonzer, 2015; Raunig, Scharler, and Sindermann, forthcoming; Valencia, 2013). They find that increases in uncertainty have a negative effect on bank lending. However, they also document that the negative relationship is mostly driven by banks that are less capitalized or have low liquidity buffers. These results do not necessarily contradict the findings of this paper. Poorly capitalized banks reduce lending when uncertainty increases. They are not concerned with long-term motives and do not maintain relationship lending. In contrast, highly capitalized banks acquire additional information when uncertainty rises, the value of relationship lending rises, and they continue to lend both to safer and riskier borrowers at lower rates. Due to the capital buffer, these banks can continue to lend to borrowers with relatively uncertain prospects without raising the probability of bank default.

Section 2 presents the construction of the idiosyncratic uncertainty proxies and describes the measures for the costs of external finance. Section 3 empirically investigates the effects of uncertainty shocks on corporate bond yields and bank loan rates; robustness tests are also presented. Section 4 provides context for the empirical results using a partial equilibrium model. Section 5 concludes.

[6]Another possible explanation for why lending rates do not increase in times of elevated risk involves problems of adverse selection or moral hazard. Banks may be reluctant to raise interest rates because this may shift the composition of their loan portfolio towards borrowers with riskier projects (adverse selection) or because they fear that borrowers will switch to riskier projects (moral hazard). Appendix C takes an analytical look at these two arguments, and finds that banks raise loan rates regardless of whether risk increases for all types of borrowers or for all types of projects. Therefore, the presence of adverse selection or moral hazard cannot explain why lending rates fall when risk increases.

2 Measuring Uncertainty and the Costs of External Finance

This section presents the construction of the idiosyncratic uncertainty proxies and describes the series that reflect the costs of external finance.

I follow Bachmann et al. (2013) in constructing the idiosyncratic uncertainty proxies for the United States and Germany. For the United States, I use data from the BOS, which is conducted monthly by the Federal Reserve Bank of Philadelphia. The uncertainty proxy $FDISP^{US}$ is the dispersion of firms' forecasts about the general business outlook.[7] For Germany, I rely on manufacturing firms' responses to the IFO-BCS, which is conducted on a monthly basis. The uncertainty proxy $FDISP^{GER}$ is calculated as the cross-sectional dispersion of expectations about future production. Bachmann et al. (2013) show that both uncertainty measures are countercyclical and positively correlated with other uncertainty proxies.

For the United States, I take the loan rate of commercial and industrial loans with an initial interest rate fixation of up to one year.[8] This series is part of the Survey of Terms of Business Lending (STBL) and is collected quarterly from a random sample of about 300 U.S. banks (Brady, English, and Nelson, 1998). Due to the lower frequency, I interpolate the series with the monthly available prime rate as an interpolator variable using the Chow-Lin procedure.[9] Loans with a maturity of up to one year cover about 94% of all commercial and industrial loans. For Germany, I use the loan rate of new loans to nonfinancial corporations in Germany with an initial interest rate fixation of up to one year. This series is part of the MFI interest rate statistics and is collected monthly by the Deutsche Bundesbank from a representative sample of 200–240 banks in Germany. The reported interest rates are weighted with the respective volume of new business loans, which are also reported by the banks, to derive an average interest rate. Loans with a maturity of one year cover around 82% of all new loans to nonfinancial corporations. In 2003, the national interest rate statistics of all countries in the Eurozone were harmonized. Differences in the methodology of interest rate

[7] A more detailed description of the proxies is presented in Appendix A.

[8] The rate is constructed as the volume-weighted average of the rates of loans with a repricing interval of zero, daily, 2 to 30 days, and 31 to 365 days. The volume weighted average maturity of these loans is 474 days for the period 2003:Q1–2016:Q2, which is a bit longer than a year. Therefore, I associate bank loans with a maturity of one year and use the expressions "repricing interval" and "maturity" interchangeably throughout the paper.

[9] The prime rate is the rate charged by the majority of the largest 25 U.S. commercial banks on many of their (short-term) commercial loans and is an indicator for many other loan rates. At a quarterly frequency, the prime rate and the loan rate from the STBL are highly correlated; the correlation coefficient is 0.99.

statistics before and after 2003 makes it difficult to compare the loan rates (see Deutsche Bundesbank, 2004); therefore, this paper only looks at the period since 2003.

For the United States, I use the corporate bond yield for maturities between one and three years. The yield tracks the performance of outstanding bonds issued by investment-grade U.S. corporations. For Germany, I rely on yields from outstanding bonds issued by German nonfinancial corporations. These include securities with a maturity of more than four years, the yields of the individual securities are weighted by the amounts outstanding at market prices. The average maturity of these bonds is six years in the period 2003-2015.[10] To my knowledge, other indexes are not available because of the relatively small market for German corporate bonds.

Figure 2 plots the time series of the uncertainty proxies, bond yields, and bank lending rates for the United States and Germany. For illustrative purposes, the monthly series are averaged to a quarterly frequency. The uncertainty measures are demeaned and normalized by their standard deviation. The upper two panels show the uncertainty proxies and the corporate bond yields for the United States and Germany for the time period 2003:Q1–2016:Q2. In both countries, uncertainty and the corporate bond yield co-move; for the United States, the correlation coefficient is 0.54, for Germany it is 0.16. The lower two panels plot the uncertainty proxies and the bank loan rates for the United States and Germany. The co-movement between uncertainty and the bank loan rate is less pronounced in the United States; the correlation coefficient is 0.30. In Germany, the two series are negatively correlated with a coefficient of –0.39.

3 Empirical Evidence

In this section, I use standard vector autoregressions (VARs) to analyze how capital markets and banks respond to surprise increases in uncertainty. I am particularly interested in the responses of corporate bond yields and bank loan rates. I employ data from both the United States and Germany.

3.1 Baseline Results

Two VARs are estimated for each country. The baseline VARs consist of three variables: a proxy for uncertainty, a measure for the cost of external finance, and the government bond yield as a measure for the riskless rate. The cost of external finance is either the

[10] I thank Anja Huck from the Deutsche Bundesbank for providing me with this information.

yield on corporate bonds or the bank loan rate.[11] As the riskless rate I use the one-year government bond yield of the respective country, with the exception of the model with the German corporate bond yield, which includes the German government bond yield with a six-year maturity.[12] The sample period is from 2003:M1 to 2016:M6. The VARs are at a monthly frequency and estimated with a constant. The lag length is set to three in all models.[13] Uncertainty is ordered before the interest rate variables in a recursive identification. Innovations in uncertainty, therefore, have an immediate impact on the interest rate variables. Following the argument of Leduc and Liu (2016), this ordering can be justified by the fact that survey respondents in the IFO-BCS (BOS) answer by the middle of month t (by the first week of month t). Therefore, they do not have complete information about interest rates in month t and the information set contains only realizations of interest rates up to month $t-1$. A similar ordering is found in Gilchrist et al. (2014). In the following, I consider unit shocks to the standardized uncertainty series to ensure that possible differences in the impulse responses between the United States and Germany can be traced back to differences in the transmission mechanism and not to differences in the shock size.

Figure 3 plots the impulse responses from the four separate VARs for the United States and Germany after an innovation to $FDISP^{US}$ and $FDISP^{GER}$, respectively. The results for the United States are shown in the first and third rows; the second and fourth rows cover the responses for Germany. The responses in the first two rows are based on the models with corporate bond yields. The impulse responses of the spread variables are calculated as the difference between each of the responses of the cost of external finance and the riskless rate. In both countries, the corporate bond yields and government bond yields move in *opposite* directions. The government bond yields decrease, with a minimum after about a year, signaling an increase in demand for government bonds consistent with a flight to safety. In contrast, the corporate bond yields increase. In the United States, the cost of corporate bond finance reaches a peak of about 20 basis points after four months; in Germany the maximum amounts to around 10 basis points after three months. The yield reverts back more slowly in the United States than it does in Germany. The spread between the corporate bond yield and the riskless rate rises in both countries. The spreads increase by roughly 10 basis points on impact, respectively, and reach a maximum of around 20 basis points after five months in

[11] For the United States, the yield on corporate bonds includes bonds with a maturity between one and three years. I rely on this type of maturity so as to be as close as possible to the maturity of bank loans. Alternatively, I use the 30-year Baa-rated corporate bond yield index, a commonly used index in the uncertainty literature (see, e.g., Bachmann et al., 2013), along with the corresponding 30-year government bond yield, which yields similar results.

[12] For the United States, the model with corporate bond yields and the U.S. government bond yield with a three-year maturity yields quantitatively similar results.

[13] The BIC criterion suggests between one and two lags for the different models, the AIC criterion between two and 10 lags. Therefore, a lag length of three falls in the middle of these suggested values.

the United States and after 3 months in Germany. The following decreases are more gradual in the United States than in Germany.

The responses based on the models with bank loan rates are shown in the last two rows of Figure 3. In both countries, the bank loan rates and government bond yields move in the *same* direction. In the United States, the loan rate reaches its minimum of –10 basis points after four months and returns to equilibrium relatively quickly. Loan rates in Germany fall for one and a half years and revert back slowly. The minimum amounts to roughly –30 basis points. The spread between the bank loan rate and the riskless rate does not change significantly in the United States. In Germany, the loan spread increases but not as much as the bond spread. The maximum increase is less than 10 basis points and occurs after 3 months. The return to equilibrium is gradual.

The results from the baseline VARs show that an unexpected increase in uncertainty leads to an increase in corporate bond yields and a decline in bank lending rates. The costs of bank and bond finance diverge in times of heightened uncertainty. A potential explanation for this finding is that bond investors want to be compensated for the higher borrower default risk and demand higher risk premia. In contrast, banks are specialized in resolving informational problems. When uncertainty increases, banks acquire additional information about the borrower in order to reduce uncertainty. This has two effects. First, lowering uncertainty about a project's return dampens the increase in the expected borrower default, which attenuates the increase in the lending rate. Second, having more information about the borrower's environment strengthens the bank's information monopoly and it can charge higher markups. This increases the bank's incentive to maintain its relationship with the customer by lowering the lending rate during periods of heightened uncertainty.

3.2 Robustness

The results from the baseline models reveal that loan rates fall and corporate bond yields rise after changes in uncertainty. I now conduct a battery of tests to check the robustness of the baseline results.

Bank loan rates are influenced by a changing composition of borrowers. Following a rise in uncertainty, banks may prefer to lend less to risky borrowers and increase the amount of loans to firms with relatively safe projects. Therefore, lower average lending rates in periods of uncertainty could simply be due to a change in the composition of the banks' loan portfolio. Note that uncertainty should hardly affect the cost of relatively safe loans. Risky loans, if they are even granted, should be offered at higher rates to compensate the lender. The STBL data allow calculating loan rates separately for different borrower types. In the survey, banks report risk ratings for their loans. Loans are classified as having either minimal, low, moderate, or acceptable risk.[14] If portfolio composition was the principal explanation for falling average rates, one would expect the rate on loans in the acceptable-risk category to increase during periods of heightened uncertainty, while the rate on relatively safe loans should remain broadly unchanged. Figure 4 plots the impulse responses of the rates on loans from each of the four risk categories to the same uncertainty shock. In response to a surprise increase in uncertainty, the rates on loans in all four risk categories fall. Quantitatively, the decrease is very similar. Therefore, in periods of elevated uncertainty, loan rates do not vary conditional on the riskiness of the borrowers. Even relatively risky borrowers are charged lower lending rates when uncertainty increases. As this exercise only looks at rates, not loan volumes, uncertainty may still induce banks to shift their portfolio toward safer loans, but this does not explain why loan rates fall for all risk types.

A differentiation of loan rates with respect to risk category is not available for Germany. As a proxy, I separately estimate the VAR with rates on loans below a volume of 1 Mio Euro and above 1 Mio Euro. As before, I look at loans with an initial interest rate fixation of up to one year. For the period 2003:M1 to 2016:M6, the average rates for the two categories are 4.1% and 3.0%, respectively, which may be an indication that smaller loans are riskier than bigger loans. Results are depicted in Panel (a) of Figure 5. Qualitatively, there are no differences between the responses of the two rates after an uncertainty shock. Quantitatively, the decrease in the rate for smaller loans is a bit more pronounced compared to the fall in the cost of larger loans. Therefore, risk shifting may not explain the decrease in the overall loan rate in Germany either.

The next robustness check tackles the issue of compositional changes from a different direction. During the financial crisis of 2007–2009, Adrian, Colla, and Shin (2013) find that bank lending declined and firms shifted toward the capital market for financing, at a time when corporate bond yields increased more than bank loan rates (De Fiore and Uhlig, 2015). In their model, De Fiore and Uhlig (2015) argue that the cost of market finance rises because the average default risk of the pool of bond-financed firms increases. Even though firms with a high risk of default stop borrowing from banks, the cost of bank finance increases, albeit to a smaller extent than bond yields. This is because firms with intermediate risk switch from bank to bond finance. To analyze whether there are dynamic effects between the costs of bond and bank finance, I include both the loan rate and the corporate bond yield in the VAR. The results are shown in Panel (b) of Figure 5.[15] In both countries the impulse responses are

[14] Brady et al. (1998) provide precise definitions for the risk classifications.

[15] As the corporate bond yield and the loan rate in Germany have different maturities, the German VAR includes two riskless rates (government bond yields with a maturity of one year and of six years). The VAR for the United States includes only the one-year government bond yield because both the cost of market debt and bank loans have roughly the same maturity.

similar to the baseline results. The costs of bond finance increase and bank finance becomes cheaper. However, there are some interactions between the two variables. In the United States, the increase in corporate bond yields is not as persistent and lending rates fall to a smaller extent compared to the baseline responses. Similarly, German bank loan rates do not decrease as much. However, the increase in the German bond yield is larger than in the baseline. In sum, there are some dynamic effects between the costs of bond and bank finance. However, the interaction is not large enough to change the finding of higher bond yields and lower lending rates during periods of elevated uncertainty.

Building on the previous robustness check, I extend the VARs to include loan and corporate bond volumes. This is done to check whether (i) the increase in the cost of bond finance is due to an increase in bond issues and (ii) the reduction in the bank loan rate is explained by a fall in the volume of new loans. The former could be interpreted as an increase in the supply of bonds, the latter as a reduction in loan demand. I use Bayesian estimation techniques in this robustness test because of the relatively large number of variables compared to the short sample period. The model for the United States is estimated at a quarterly frequency because data on the volumes of loans and corporate bonds are available only at this frequency.[16] The models include additional information in the form of a Minnesota-type prior. For the uncertainty series, I impose the prior belief of white noise; for the other variables, that of a random walk.[17] Figure 6 presents the results. In the United States, an increase in uncertainty raises the volume of both corporate bonds and bank loans.[18] On impact, bonds increase by about 0.05 standard deviations, while loans rise by 0.3 standard deviations. These increases are short-lived; the volumes are back in equilibrium after two quarters. In Germany, bank loans increase by 0.2 standard deviations on impact, followed by a quick return to equilibrium and a prolonged undershoot after two quarters. In contrast, corporate bonds do not react significantly to a sudden change in uncertainty. In sum, these findings show that the reduction in bank loan rates cannot be explained by a reduction in loan volumes at the aggregate level. If anything, the amount of loans increases as uncertainty rises, indicating that most of the banks attempt to alleviate the negative effects of uncertainty on firms in the short term.

[16] The monthly government bond yield and the uncertainty proxy is averaged to a quarterly frequency. As loan rate, I use the original, not interpolated, loan rate series.

[17] Technically, the hyperparameter δ_{unc} for uncertainty is set to 0, the hyperparameters for the other variables are equal to 1. The hyperparameter λ is calibrated to 0.25, which is in line with Banbura, Giannone, and Reichlin (2010), who set λ to 0.262 in a VAR with seven variables. The impulse responses are computed by generating 5,000 draws from the posterior.

[18] This model also allows discovering whether the interpolation of the U.S. loan rate from a quarterly to a monthly frequency biases the results. The lending rate drops by 0.1 percentage points on impact and remains significantly below the equilibrium rate for roughly a year, which is similar to the finding from the monthly model.

In the final robustness check, I extend the baseline model to include two additional variables–real activity and a policy rate measure. For activity I take the log of production and order it first in the system. Activity reacts to changes in uncertainty with a lag. As policy rate I use the effective federal funds rate for the United States; for Germany it is the Euro Overnight Index Average (EONIA). The policy rate is ordered last, reflecting the idea that uncertainty has an immediate effect on short-term interest rates. Due to the relative large number of variables, the models include additional information in the form of a Minnesota-type prior as in the previous robustness check. For the uncertainty series, I impose the prior belief of white noise; for the other variables, that of a random walk. The impulse responses are depicted in Figure 7. In both countries, production falls as uncertainty suddenly rises, and monetary policy becomes more expansionary. The reduction in policy rates is stronger compared to the decrease in government bond yields. The baseline results are confirmed: the costs of bond finance increase, while those of bank finance fall. For the United States, the maximum changes are roughly halfed compared to the baseline. In Germany, bank loan rates become less persistent; however, the magnitude of the decrease is similar to that of the baseline. In contrast, corporate bond yields increase by a larger amount and the response is also more persistent.

4 Partial Equilibrium Model of Lending Behavior

The empirical part of this paper shows that uncertainty is accompanied by increases in the cost of bond finance and a reduction in the cost of bank loans. To explain these opposite reactions, this section presents a partial equilibrium model that looks separately at the behavior of the debt market and the banking sector in times of heightened uncertainty.

The model consists of two periods, $t=1,2$, and two types of lenders–the capital market and a bank–from which firms borrow. All agents are risk (and ambiguity) neutral. Firms do not have own resources for their projects and therefore borrow from a lender. Firms do not individually decide on what type of financing they will pursue (see, e.g., Holmstrom and Tirole, 1997); instead, one set of firms borrows from the capital market, and another set receives loans from banks.[19] Apart from this, there is no ex-ante heterogeneity among firms. Investment projects are started at the beginning of the period and terminate at the end of the same period. The investment yields a stochastic payoff $x_t \in [\underline{x}, \bar{x}]$, which is uniformly distributed. Following Diamond (1984) and Gale and Hellwig (1985), there is an asymmetric

[19] This is in line with empirical evidence indicating that only a relative small fraction of firms has the ability to switch from bank to bond finance, both in the United States and in Germany (see, e.g., Hainz and Wiegand, 2013; Himmelberg and Morgan, 1995).

information problem between borrowers and lenders. The distribution from which the payoffs are drawn is known to all agents. The actual draw is the firm's private information; the lender can observe the payoff shock x_t only by taking over the project. Monitoring and liquidating the project involves costs $\bar{\mu}$.

There are two sources of uncertainty in the model–risk and ambiguity (Knightian uncertainty). Risk σ raises the dispersion of the baseline distribution from which the payoff shocks are drawn, $x \in [\underline{x} - \sigma, \bar{x} + \sigma]$. However, changes in risk cannot be perfectly observed by borrowers and lenders as it is accompanied by ambiguity, denoted by parameter a. Firms and lenders become less certain about what the exact distribution of firm returns may be. They have a set of beliefs about the dispersion of this new distribution. In the spirit of Ilut and Schneider (2014), the set of beliefs is parametrized by the interval of dispersions centered around the true dispersion σ:

$$\sigma_a \in [\sigma(1-a),\, \sigma(1+a)] \ . \tag{1}$$

Without acquiring extra information, agents observe the set of dispersions, σ_a, instead of the true size of risk σ.[20] The worst-case dispersion from this belief set is the highest dispersion because, given the lending rate, it implies a higher expected probability of borrower default compared to what the lowest value implies. Both higher risk and higher ambiguity imply a more dispersed set of beliefs and a higher worst-case dispersion. Agents, who have ambiguous belief sets, choose the worst-case dispersion when evaluating their profits:

$$\sigma_a^* = \max\,[\sigma(1-a),\, \sigma(1+a)] \ . \tag{2}$$

They do so because maximizing the lender's profit with respect to the highest possible dispersion results in lower (ex-post) absolute forecast errors compared to the lowest possible dispersion.[21] Therefore, unlike Ilut and Schneider (2014), the agents do not need to be ambiguity averse.

Risk and ambiguity materialize at the beginning of $t=1$ and dissolve at the end of the first period once the lender is repaid or default occurs. Therefore, the first period denotes the short-run period during which uncertainty is elevated. The second period represents the

[20] The concept of ambiguity as used in this paper deviates from that of Ilut and Schneider (2014). In this paper, ambiguity is about the dispersion instead of the mean. Therefore, risk and ambiguity are linked to each other. If risk is positive, $\sigma > 0$, there is ambiguity about the true size of risk. If risk is zero, $\sigma = 0$, there is no ambiguity. In the latter case, agents can assign correct probabilities to all outcomes, and they maximize with respect to the distribution $x \in [\underline{x}, \bar{x}]$. In addition, and as shown later, this formulation of ambiguity does not require that the agents are ambiguity averse.

[21] The proof for this result is presented in Appendix D.

long-run equilibrium in which uncertainty is assumed to be zero, $\sigma_a^* = 0$. However, payoffs are still stochastic, $x_t \in [\underline{x}, \bar{x}]$, in Period 2.

4.1 Capital Market

At the beginning of the first and second periods, one set of firms borrows from the capital market. If the borrower does not default at the end of $t=1$, the capital market receives repayment of the debt, and the contract ends. A firm that defaults is replaced by a new firm, so that a new contract between borrower and lender can take place in Period 2. The capital market relies on publicly available information about the borrower and does not invest in acquiring additional information. Therefore, the structure of the one-period contract does not change from the first to the second period. The one-period problem follows the outline of Williamson (1987) and Walsh (2003).

A firm that borrows from the capital market is able to pay back its debt whenever its revenue, x_t, is larger than its debt, $R_t^C \cdot L_t$, where R_t^C is the cost of bond finance and L_t is the volume of direct credit. Each project requires an investment of one unit; therefore, $L_t = 1$ holds for both periods. If the firm announces a revenue $x_t \geq \hat{x}_t$, it repays the loan. $\hat{x}_t$ is the threshold level at which the firm earns just enough from the project to pay back its debt R_t^C, which implies that $\hat{x}_t = R_t^C$. After paying back its debt, the firm keeps the residual $(x_t - R_t^C)$. The firm defaults if $x_t < \hat{x}_t$; the bond investor monitors the firm, $\bar{\mu}$ is lost in the bankruptcy procedure, and the lender receives $(x_t - \bar{\mu})$. Defaulting firms receive nothing. Taking into account that risk σ and ambiguity a rise at the beginning of the first period, a firm borrows from the capital market in Period 1 only if its expected return is not smaller than zero:

$$E_1 \left\{ \int_{R_1^C}^{\bar{x}+\sigma_a^*} (x - R_1^C)\, dF(x) \right\} \geq 0 \ . \tag{3}$$

The structure of the expected return to firms in the second period is similar, except that $\sigma = 0$ and R_1^C is replaced by R_2^C.

The expected return to the market lender in Period 1 is

$$E_1 \left\{ \int_{\underline{x}-\sigma_a^*}^{R_1^C} [x_1 - \bar{\mu}]\ dF(x) + \int_{R_1^C}^{\bar{x}+\sigma_a^*} R_1^C\ dF(x) \right\} \ . \tag{4}$$

The first term in Equation (4) is the return to the lender if the borrower defaults, which occurs whenever the project payoff x_1 is smaller than R_1^C. The second term is the return to the lender if the borrower does not default, which holds whenever $x_1 \geq R_1^C$.

Following Afanasyeva and Güntner (2014), the debt contract is formulated from the lender's perspective, which ensures that the bond investors take an active part in determining the cost of market debt. The lender maximizes its expected return (Equation (4)) with respect to the cost of bond finance, R_1^C, subject to the borrower's participation constraint (Equation (3)). The first-order condition is:[22]

$$R_1^C = \bar{x} - \bar{\mu} + \sigma_a^* \ .$$

An increase in uncertainty σ_a^* raises the cost of market debt R_1^C. Bond investors demand to be compensated for the increased probability of borrower default. This constitutes the *risk compensation channel* and is a standard result of a model with CSV. An increase in monitoring costs $\bar{\mu}$ lowers the cost of market finance. Firms do not have resources of their own; in case of default, they do not lose their net worth, and the lenders bear the costs. A higher $\bar{\mu}$ makes borrower default more costly for the lender. The lender decreases R_1^C in order to reduce the likelihood of default.

Turning to Period 2, risk σ disappears and lenders only need to be compensated for the normal risk stemming from the stochastic payoff $x_2 \in [\underline{x}, \bar{x}]$. Bond financing becomes less costly compared to Period 1:

$$R_2^C = \bar{x} - \bar{\mu} \ . \tag{5}$$

4.2 Banking Sector

One set of firms borrows from the bank at the beginning of the first and second periods. In contrast to the capital market, the bank builds long-term relationships with its borrowers, which provides the bank with two benefits. First, firms reveal *proprietary information* to the bank at no cost during Period 1. This information is not publicly distributed because, if it was, the firm's competitors could profit from it (Bhattacharya and Chiesa, 1995). Sharing this information lessens information asymmetries between the firm and the bank in the second period: monitoring costs in Period 1, $\bar{\mu}$, decrease to $(1-e)\,\bar{\mu}$ in Period 2, given that firms survive the first period. The parameter e is between 0 and 1 and governs how much narrower the information asymmetries are between the borrower and the lender in Period 2 compared to Period 1. The higher the parameter e, the greater the flow of private information from the firm to the bank. Second, the bank may acquire additional costly *market information* in Period 1. This information is not known to the firm. More information I about the market in which the firm operates reduces the bank's losses in the event the borrower defaults. Bankruptcy

[22] The complementary slackness condition implies that the borrower's participation constraint (Equation (3)) only binds for $\bar{\mu} = 0$. Since this is a model of asymmetric information, $\bar{\mu} > 0$ holds, and the Lagrange parameter can be dropped. This argument holds for the second period also. The reason the constraint never binds is that firms do not have any resources of their own. Therefore, they cannot lose any net worth when they default. This means that firms never make negative profits. As there are always some situations in which firms make positive profits, the firms' expected profits have to be larger than zero.

costs in the second period are lower by the amount $c \cdot I$, where c is a parameter governing how much a unit of information reduces the default costs. c can take values between 0 and $(1-e)\bar{\mu}$, where the upper bound arises from the fact that the bankruptcy costs in the second period cannot be smaller than zero. Information I is between $[0,1]$; a value of 0 implies no additional market information, a value of 1 stands for full information.

Market information I comes along with an additional benefit. It reduces the uncertainty of investment projects in the first period by lowering the ambiguous component a. The original set of beliefs, described by expression (1), changes to:

$$\sigma_{a(I)} \in \left[\sigma\left(1-a\left[1-I\right]\right), \, \sigma\left(1+a\left[1-I\right]\right)\right] \ .$$

The bank can reduce ambiguity to zero if it has full information, $I=1$, however, this does not lower risk σ. The bank shares the information I with the borrower as part of the relationship. All agents take the worst-case dispersion when they evaluate their plans, $\sigma^*_{a(I)} = \max\ \sigma_{a(I)}$, which is smaller than σ^*_a from Equation (2), the worst-case dispersion that lenders and borrowers on the capital market can experience.

In collecting market information, the bank has to pay two types of costs. First, to investigate the market in which the borrower operates in more detail, the bank is required to shift resources within the bank. By doing so, the bank incurs a fixed cost $K_{I>0}$ irrespective of the amount of acquired information. Second, rapidly increasing the amount of information results in higher costs. The bank is faced with adjustment costs $\kappa \cdot \frac{1}{1-I}$; the costs are parametrized by κ.

The bank can reap the benefits from private information and some of the gains from information about the business environment only in the second period, and only if the firm does not default in the first period. Therefore, the bank takes into account that its actions in Period 1 have an impact on its return in Period 2. If the borrower does not default in Period 1, the bank rolls over the loan to Period 2 and profits from the informational advantage. If the borrower defaults in the first period, the bank can lend to a different firm in the second period with the drawback of having no particular information about the new firm. The expected return to the bank is

$$E_1\left\{\int_{\underline{x}-\sigma^*_{a(I)}}^{R_1^B}[x_1-\bar{\mu}]\,dF(x)+\int_{R_1^B}^{\bar{x}+\sigma^*_{a(I)}}R_1^B\,dF(x)-K_{I>0}\,-\frac{\kappa}{2}I^2\right.$$
$$+\left(1-\int_{\underline{x}-\sigma^*_{a(I)}}^{R_1^B}dF(x)\right)\left(\int_{\underline{x}}^{R_2^B}\left[x_2-\bar{\mu}^B(I)\right]\,dF(x)+\int_{R_2^B}^{\bar{x}}R_2^B\,dF(x)\right)$$
$$\left.+\left(\int_{\underline{x}-\sigma^*_{a(I)}}^{R_1^B}dF(x)\right)\left(\int_{\underline{x}}^{\tilde{R}_2^B}[x_2-\bar{\mu}]\,dF(x)+\int_{\tilde{R}_2^B}^{\bar{x}}\tilde{R}_2^B\,dF(x)\right)\right\}\;, \tag{6}$$

where R_1^B and R_2^B are the loan rates the relationship firm has to pay to the bank in Periods 1 and 2, respectively, $\bar{\mu}^B(I)=[(1-e)\bar{\mu}-c\cdot I]$ are the costs of bankruptcy of relationship firms in the second period, and $\tilde{R}_2^B$ is the loan rate paid by a no-relationship firm in Period 2. The first line of Equation (6) describes the expected return in Period 1. The first term represents the expected profit to the bank if the borrower defaults. The lender monitors and liquidates the firm's assets; the amount $\bar{\mu}$ is lost during this procedure. If the borrower does not default, the lender receives the interest rate R_1^B; the expected return for this situation is denoted by the second term. The costs associated with acquiring market information are described by the third and fourth term.

The second line of Equation (6) accounts for the fact that the decision about the rate R_1^B and information I not only affects the outcome in Period 1, but also in $t=2$. An increase in R_1^B raises the probability that the borrower defaults in the first period, ceteris paribus, and reduces the likelihood that the bank can continue the relationship with the borrower in Period 2. This is represented by the first term in parentheses. The second term in parentheses describes the expected return from continuing the relationship. The benefit from the relationship is a drop in the cost of borrower default from $\bar{\mu}$ to $\bar{\mu}^B(I)$; the difference is due to the terms $e\cdot\bar{\mu}$ and $c\cdot I$. The expression $e\cdot\bar{\mu}$ reflects lower informational asymmetries between the borrower and the lender. The expression $c\cdot I$ represents the idea that the lender can more easily continue the project when the borrower defaults due to its additional information about the environment in which the project is based.

If the firm defaults in the first period, the bank can still lend to a different firm in the second period and charge the loan rate $\tilde{R}_2^B$. However, in this case, the bank cannot profit from lower informational asymmetries and the acquired information I is also useless in evaluating the new firm's project. This is denoted by the third line in Equation (6).

A firm that forms a relationship with the bank only borrows from the bank if its expected profit is non-negative across the two periods:

$$E_1\left\{\int_{R_1^B}^{\bar{x}+\sigma^*_{a(I)}}\left[x_1-R_1^B\right]\,dF(x)+\left(1-\int_{\underline{x}-\sigma^*_{a(I)}}^{R_1^B}dF(x)\right)\left(\int_{R_2^B}^{\bar{x}}\left[x_2-R_2^B\right]\,dF(x)\right)\right\}\geq 0\ . \quad (7)$$

The first term in Equation (7) is the firm's expected profit in the first period. If a firm does not default in $t=1$, denoted by the expression in the first set of parentheses, it borrows again from the bank to finance a second investment from which it expects a profit, described by the second set of parentheses.

The bank's problem is to choose the lending rates R_1^B, R_2^B, and $\tilde{R}_2^B$ and the amount of information I to maximize Equation (6) subject to the borrower's participation constraints, denoted by Equation (7) and Equation (3) with $\tilde{R}_2^B=R_1^C$ and $\sigma^*_a=0$. Analytical results can only be calculated for the three loan rates, the optimal amount of information I needs to be simulated. R_1^B, R_2^B, and $\tilde{R}_2^B$ are[23]

$$\tilde{R}_2^B=\bar{x}-\bar{\mu} \quad (8)$$

$$R_2^B=\bar{x}-\bar{\mu}^B(I) \quad (9)$$

$$R_1^B=\bar{x}-\bar{\mu}+\sigma^*_{a(I)}-\frac{1}{\bar{x}-\underline{x}}\left\{(\bar{x}-\underline{x})\left(\bar{\mu}-\bar{\mu}^B(I)\right)-\frac{1}{2}\left[(\bar{\mu})^2-(\bar{\mu}^B(I))^2\right]\right\}\ . \quad (10)$$

If the borrower defaults in $t=1$, the bank can lend to a different firm in the second period and demand the loan rate $\tilde{R}_2^B$ (Equation (8)). This rate equals the cost of bond finance in Period 2 (Equation (5)) because the bank has no private information about this new firm nor any information about the business environment in which it operates.

Equation (9) denotes the loan rate paid in Period 2 if the borrower does not default in either period. Compared to the cost of bond finance in Period 2 (Equation (5)) or the loan rate the bank charges a no-relationship-firm (Equation (8)), the bank lending rate is larger by the amount $e\cdot\bar{\mu}+c\cdot I$. This represents the markup the bank can charge when it establishes a relationship with the borrower. The loan markup can increase for three reasons. First, the bank receives more proprietary information from the firm (an increase in e). Second, the bank acquires additional information about the firm's business environment (a higher I). Third, the bank may learn more from a marginal unit of this information (a rise in c). All three factors enable the lender to charger higher loan rates because the default situation is less feared by the lender since it is now less costly. These costs are borne by the lender

[23] The complementary slackness condition implies that the first participation constraint (Equation (7)) does not bind when $\bar{\mu}=\bar{\mu}^B(I)=0$. The second constraint (Equation (3)) only binds for $\bar{\mu}=0$. Therefore, the Lagrange parameters can be omitted in the subsequent analysis. The reason the constraints do not bind is explained in footnote 22.

because firms do not lose their net worth when they default. Therefore, the costs of bank finance are higher compared to bond finance in the second period, which denotes the long run. This is consistent with the data. On average, bank loan rates are higher than corporate bond yields.[24] In this way, banks can accommodate their borrowers in economically bad times (described by the first period) with more favorable loan conditions in an effort to maintain their customer relationships.

Equation (10) is the bank loan rate in Period 1. There are two channels through which the loan rate may change as uncertainty increases, and they work in opposite directions. First, given information $I = \bar{I}$, an increase in risk σ raises the cost of bank finance R_1^B:

$$\left.\frac{\partial R_1^B}{\partial \sigma}\right|_{I=\bar{I}} = 1 + a(1 - \bar{I}) > 0 \ .$$

Risk increases the probability of borrower default, and the bank demands compensation in form of a higher loan rate. This is the risk compensation channel. Second, banks may acquire more information I in times of elevated uncertainty, which puts downward pressure on the lending rate. Taking the derivative of Equation (10) with respect to I gives:

$$\frac{\partial R_1^B}{\partial I} = -\sigma \cdot a - \left[1 - \frac{(1-e)\bar{\mu}}{\bar{x} - \underline{x}} + \frac{c \cdot I}{\bar{x} - \underline{x}}\right] c < 0 \ .$$

Acquiring additional market information may make the loan rate fall for two reasons. First, it reduces ambiguity. The set of beliefs that the agents hold becomes less dispersed, which lowers the worst-case dispersion. This reduces the probability of borrower default, thereby decreasing the lending rate. Second, having collected more information in the first period, bankruptcy costs are lower in Period 2, making it more attractive for the bank to continue the relationship with the borrower in the second period. By reducing the lending rate in $t = 1$, borrower default in Period 1 becomes less likely and the bank profits from lower bankruptcy costs in Period 2. These two effects constitute the *information channel*. The next section analyzes whether the information channel can dominate the risk compensation channel.

4.3 Simulation of the Banking Sector

The risk compensation channel increases the loan rate as uncertainty rises. The information channel decreases the lending rate when uncertainty is elevated. If the latter channel dominates the former, the loan rate may fall in times of heightened uncertainty. To discover under what

[24] For example, for the United States the rate on loans with a maturity of one year is 3.75% for the time period 2003:Q1 to 2016:Q2, while the yield on corporate bonds with a maturity of one to three years is 3.15%.

conditions banks endogenously acquire more information I when uncertainty increases and whether the lending rate falls, I conduct the following simulations of the model.

4.3.1 Baseline Simulation

Table 1 summarizes the parameter values. The interval bounds $\bar{x}$ and $\underline{x}$, the monitoring costs $\bar{\mu}$, and the markup parameter e are chosen to obtain reasonable values for the default rate, and the loan rates R_2^B and $\tilde{R}_2^B$ when there is no risk, $\sigma = 0$, and no acquisition of market information, $I = 0$, for the United States. The ambiguity parameter a is set so that an increase in risk σ raises total uncertainty $\sigma^*_{a(I=0)}$ twice as much.[25] This reflects the finding of Rossi et al. (2016) that both ambiguity and risk are important components of total uncertainty.

Figure 8 presents the evolution of bank profits (left panel), calculated from Equation (6), and the loan rate in the first period (right panel), computed from Equation (10), as the amount of information increases. In the simulation, two levels of risk are compared: no risk, $\sigma = 0$ (depicted by the solid lines), and elevated risk, $\sigma > 0$ (dashed lines). Starting from a situation with no risk and no additional information about the business environment, the expected bank profit drops as the bank starts to collect some information. This is due to incurring the fixed costs of acquiring the information. As more and more information is accumulated, the expected profit increases as the higher information level reduces the cost of a borrower default in Period 2. However, profits do not monotonically rise because of the adjustment costs associated with changes in the level of information. If these costs are substantial, the gains from information do not exceed those that would have been made without any additional information; the maximum possible profit is shown by the horizontal dashed dotted line in the left panel. Therefore, the bank chooses to acquire no additional information when risk is zero. The corresponding loan rate is represented in the right panel by the point in the left-most position on the solid line.

Now, the bank observes an increase in risk. Having no additional information, the bank's profit drops substantially. Collecting the first bits of market information results in a further drop in profit due to the fixed costs. Gathering more and more information increases the profit and it becomes larger than the profit made in the absence of additional information. This is because market information not only lowers bankruptcy costs in Period 2, it also

[25] I set $\bar{x} = 10$, $\underline{x} = 2.9$, and $\bar{\mu} = 6.85$ in order to match an annualized default rate of 3.5% and a corporate bond yield of 3.15% (because $\tilde{R}_2^B = R_2^C$). $e = 0.085$ delivers a bank loan rate of 3.73%, which implies a markup on the bank loan rate of 58 basis points compared to the corporate bond yield, given $I = 0$ (because $R_2^B - \tilde{R}_2^B = e\bar{\mu}$ if $I = 0$). Ambiguity a equals 1. I calibrate c to 2.0 so that a marginal increase of market information by 0.1 increases the markup on the loan rate by 20 basis points. The fixed costs are set to 0.3, the adjustment costs to 0.025. Risk σ is set to 0. In the scenario with elevated risk, σ is calibrated to 0.2, matching the rise in the lending rate when uncertainty increases, given that there are no relationship lending motives ($e = c = 0$) which implies $R_1^B\big|_{e=c=0} = R_1^C$.

reduces ambiguity in Period 1. The set of beliefs about the distribution of project returns becomes less dispersed, resulting in a lower worst-case dispersion. The optimal amount of information has an interior solution because, from a certain amount of information onward, the cost of an additional marginal unit of information outweighs the benefit. The horizontal dotted line in the left panel indicates the maximum possible profit, the vertical dotted line marks the optimal amount of information. The right panel shows that this level of information is associated with a loan rate that is below the rate when there is no risk. Therefore, when risk is elevated, the bank reduces the lending rate due to less ambiguity and lower bankruptcy costs, which are induced by acquiring a positive amount of market information.

4.3.2 Sensitivity Analyses

The baseline simulation shows that the bank lending rate is lower in periods of elevated risk compared to times of no risk. To complete the simulation exercise, I look at the parameters potentially driving this result. The values for the following three parameters are changed one at a time: the ambiguous component a, the markup e that denotes the size of acquired private information, and the markup c that is the result of having collected additional information about the firm's business environment. The bottom part of Table 1 summarizes the values. In Figures 9 and 10, the black lines show the case of no risk, the red lines show elevated risk. The thick dotted lines are the results from the baseline simulation, the dashed dotted lines present the results when the respective parameter is larger than in the baseline, the dashed lines when the parameter is smaller, and the solid lines when the parameter is set to zero.

The two panels at the top of Figure 9 show that a higher level of ambiguity a than in the baseline increases the amount of information that is optimal. The lending rate in Period 1 is still lower than when there is no risk. If ambiguity is positive, but less than in the baseline, the amount of information is still positive but smaller than in the baseline, while the lending rate in Period 1 is still lower than the rate when there is no risk. If there is no ambiguity, $a = 0$, there are no gains in the first period from acquiring information; information only helps to increase monopoly power in the second period. However, this is not enough for the bank to lower the lending rate. Therefore, the loan rate is higher compared to the situation of no risk.

An increase in the flow of proprietary information to the bank, which corresponds to an increase in the parameter e, strengthens the bank's information monopoly in Period 2. This opens the possibility for the bank to demand higher loan rates in the second period, which increases the expected profit (see the two bottom panels in Figure 9). However, in order to take advantage of the higher monopoly power, the bank needs to ensure that the borrower does not default during the first period. Therefore, the bank charges a lower rate in Period 1 compared to the baseline simulation. In contrast, if there is a weaker flow of private information or no flow at all, $e = 0$, maintaining the relationship with the borrower loses its appeal. The lending rate is higher compared to the situation of no risk, and the bank does not collect any market information, $I = 0$.

An increase in parameter c describes a situation in which a marginal unit of market information reduces bankruptcy costs in the second period by a greater amount. In this case, it is optimal for the bank to increase its market information (see Figure 10). The bank charges a lower lending rate in the first period than in the baseline, in the hope of keeping the borrower from defaulting and maintaining the relationship up to the second period. In contrast, if information decreases default costs by only a small amount or not at all, $c = 0$, the bank does not acquire any information I, and the loan rate is above the rate charged in times of no risk. If there is no risk and c is higher than in the baseline, the bank collects a positive amount of information. However, this yields a lending rate that deviates relatively strongly from the average lending rate observed in the data. Overall, the model is relatively sensitive to the choice of the parameter c, which is not surprising given the two-period-nature of the model and given that c is the central parameter governing the importance of the second period, which is a proxy for all future periods.

In sum, banks need to be able to acquire both private and market information, so as to reduce ambiguity in Period 1 and lower bankruptcy costs in Period 2. Then they can offer lower lending rates during periods of elevated risk.

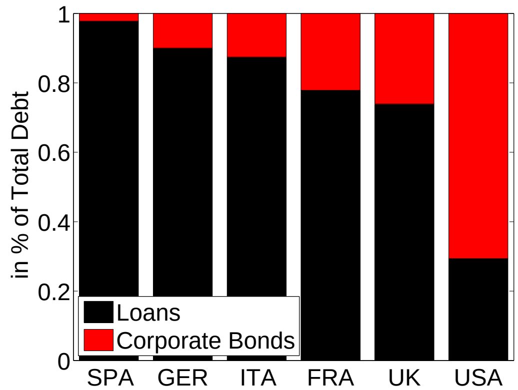
5 Conclusion

This paper shows that the costs of bond and bank finance react differently from each other in times of elevated uncertainty. Bond yields rise; loan rates fall. This difference arises because banks act to reduce informational problems, whether they are asymmetric or general in nature. In uncertain times, costly information becomes more valuable as it reduces uncertainty, thereby decreasing the likelihood of borrower default. In addition, relationships with borrowers become more important for the lenders because acquiring more information today increases the bank's information monopoly in the future, which implies higher long-term profits. Both effects lead banks to lower interest rates during periods of heightened uncertainty. In this way, banks may lessen the negative effects of uncertainty on firms in the short-term. In the long run, banks charge higher rates on average compared to the capital market so as to accommodate, at least to some extent, borrowers during economically difficult times.

However, lower interest rates in periods of uncertainty reduce banks' short-term profits. Lower profits imply that not all banks are able to cut interest rates in uncertain times. On the one hand, banks that are better capitalized may continue to lend to firms in periods of heightened uncertainty at lower rates so as to maintain their relationships with borrowers. On the other hand, weakly capitalized banks reduce their lending and cannot attempt to mitigate the adverse consequences of uncertainty for their clients. Therefore, strong capital requirements are needed as a way of counteracting the adverse effects of uncertainty on the real economy.

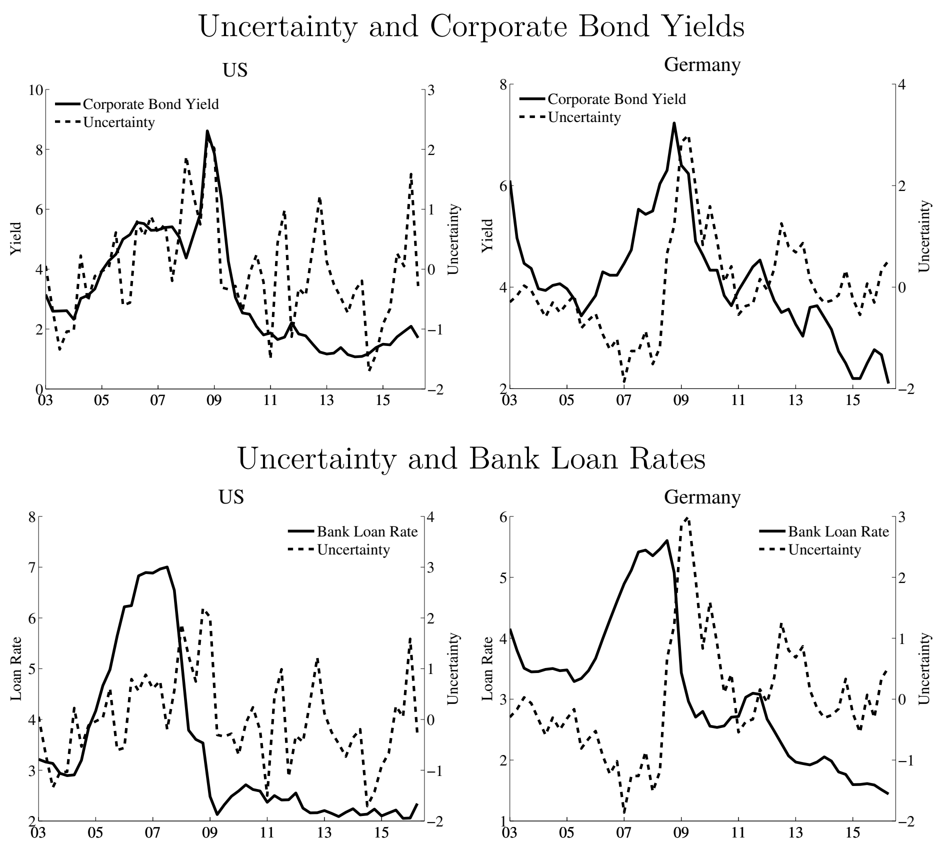
Figures

Figure 1: Debt Financing of Nonfinancial Corporations in 2015



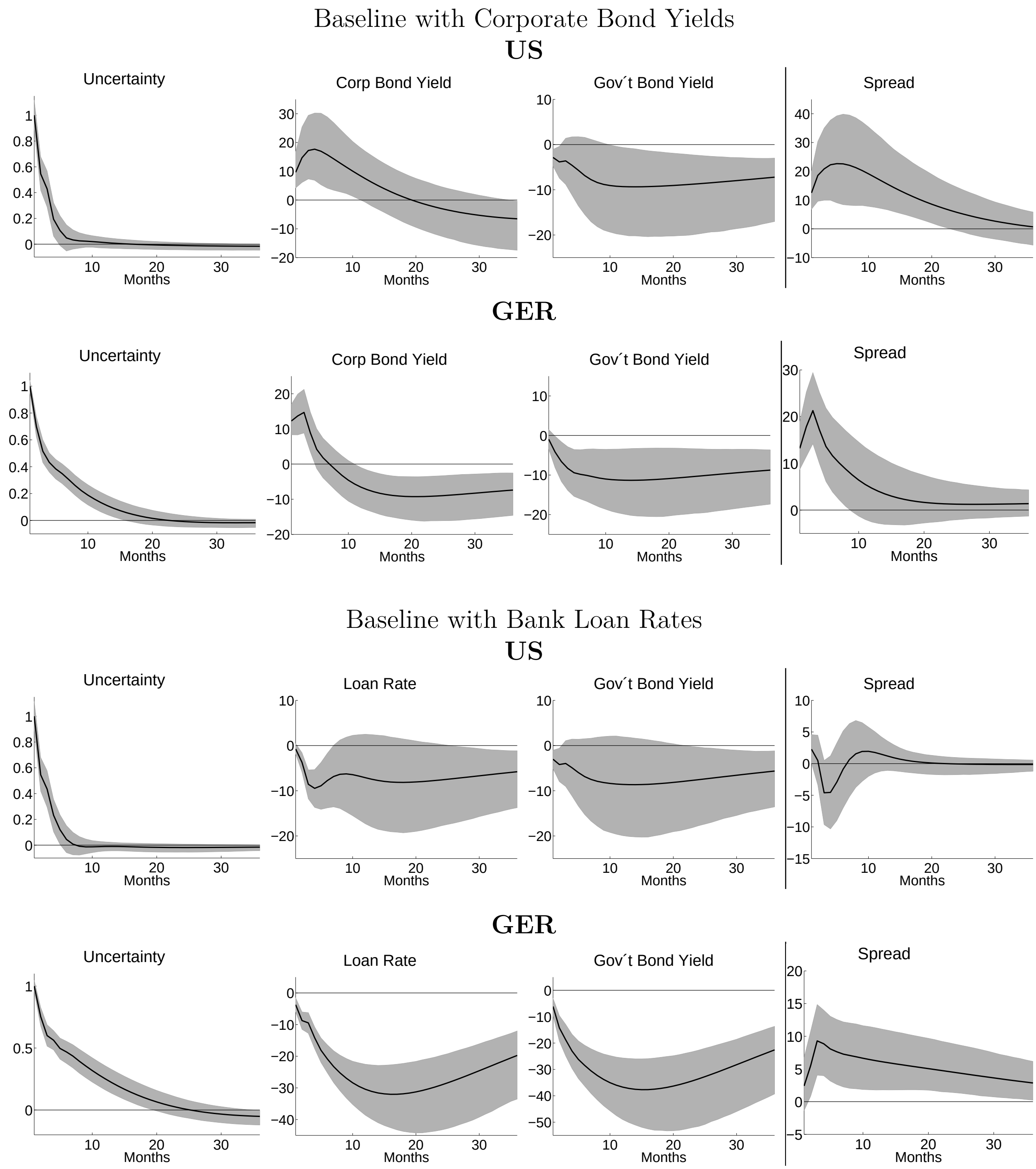
Notes: Data for Spain, Germany, Italy, France and the United Kingdom are from the financial balance sheets of Eurostat's quarterly sector accounts. For the United States, the data are from the financial accounts statistic of the Federal Reserve Board. Loans and corporate bonds as shares of total debt are calculated for 2015.

Figure 2: Uncertainty and the Costs of Bank and Bond Finance



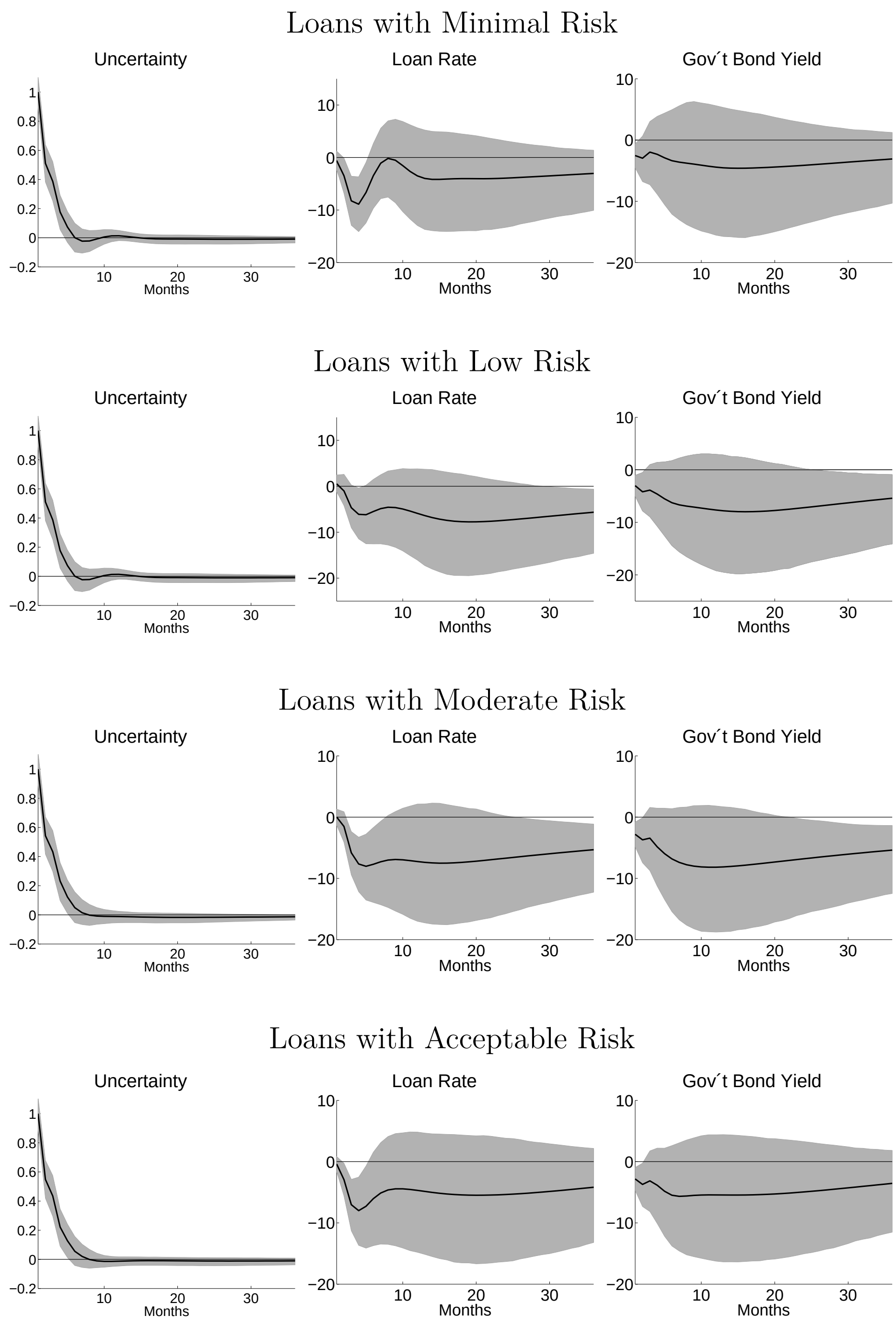
Notes: The figure shows the quarterly averages of the monthly time series, except for the U.S. loan rate, which is originally at a quarterly frequency. The uncertainty proxy for the United States, $FDISP^{US}$, is from the BOS; that for Germany, $FDISP^{GER}$, from the IFO-BCS. Both uncertainty proxies are standardized. The sample period is 2003:Q1–2016:Q2.

Figure 3: Impulse Responses to Uncertainty Shock for the United States and Germany



Notes: Effects of a unit shock to the standardized uncertainty series $FDISP^{US}$ and $FDISP^{GER}$, respectively. Uncertainty is expressed in unit values, while all other variables are expressed in basis points. Monthly VARs are estimated with three variables. Uncertainty is ordered first in a recursive identification. The responses in rows 1 and 2 are estimated with corporate bond yields, those in rows 3 and 4 with bank loan rates. The impulse responses of the spread variables are calculated as the difference between each of the responses of the cost of external finance and the riskless rate. The sample period is from 2003:M1–2016:M6. The black solid line depicts the point estimate, the shaded areas represent the 95% confidence intervals based on 5,000 bootstrap replications.

Figure 4: Robustness I: Impulse Responses to Uncertainty Shock with Three Variables for the United States: Loan Rates Conditional on Risk Type

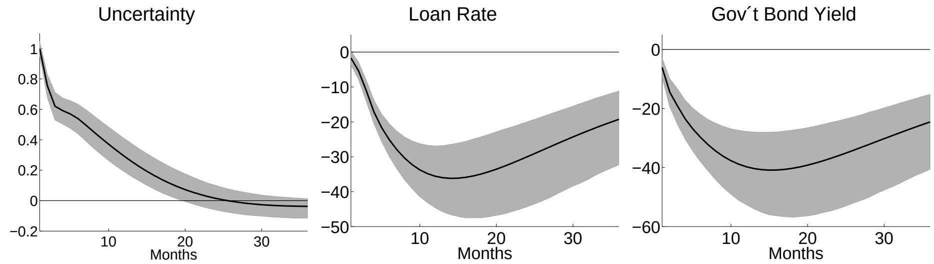


Notes: Effects of a unit shock to the standardized uncertainty series $FDISP^{US}$. Uncertainty is expressed in unit values, while all other variables are expressed in basis points. Monthly VARs are estimated with three variables. Uncertainty is ordered first in a recursive identification. The responses in row 1 are estimated with loan rates for borrowers with minimal risk, in row 2 with low risk, in row 3 with moderate risk, and row 4 with acceptable risk. The sample period is from 2003:M1–2016:M6. The black solid line depicts the point estimate, the shaded areas represent the 95% confidence intervals based on 5,000 bootstrap replications.

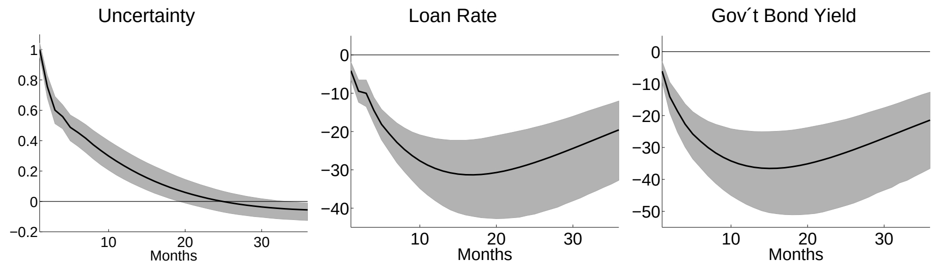
Figure 5: Robustness II: Impulse Responses to Uncertainty Shock

(a) **GER:** Loan Rates Conditional on Loan Size

Loan Rate on Loans Up to 1 Mio Euro

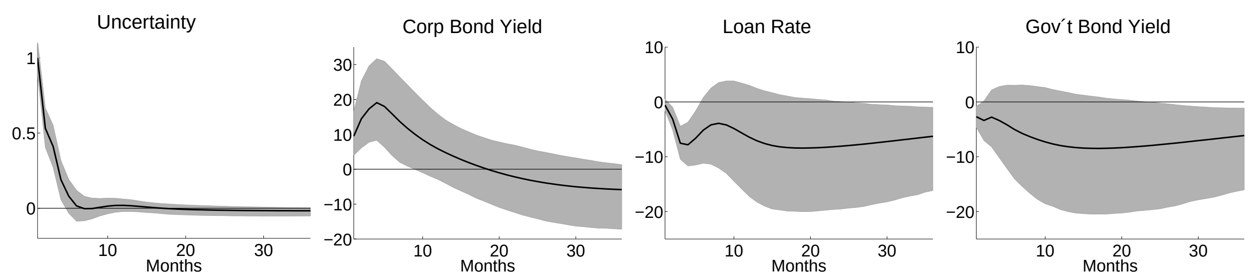


Loan Rate on Loans Over 1 Mio Euro

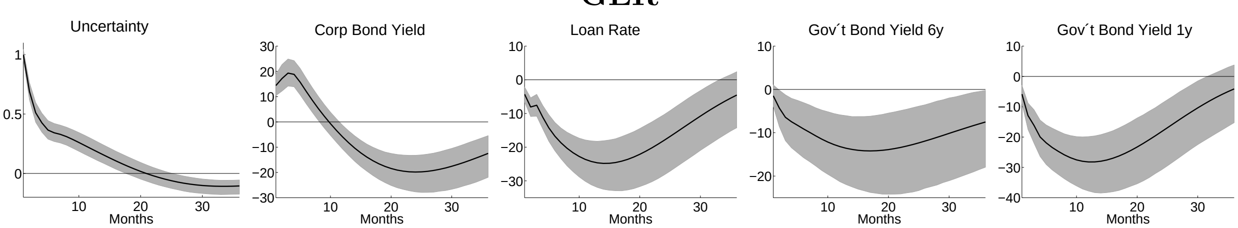


(b) Loan Rate and Corporate Bond Yield Together in One VAR

US

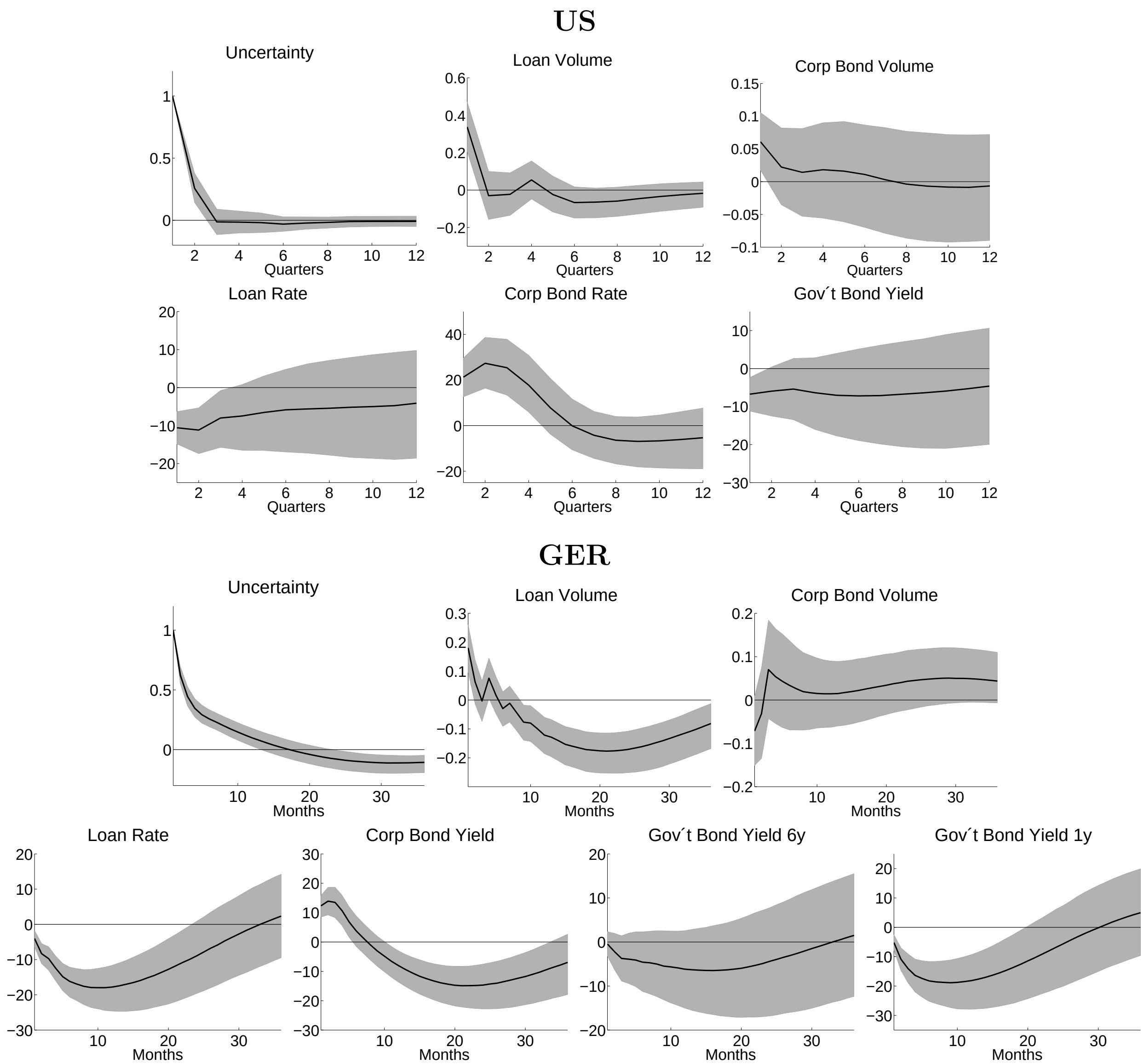


GER



Notes: Effects of a unit shock to the standardized uncertainty series $FDISP^{GER}$ or $FDISP^{US}$. Uncertainty is expressed in unit values, while all other variables are expressed in basis points. Uncertainty is ordered first in a recursive identification. The responses in row 1 are estimated with bank loan rates on loans in an amount up to 1 Mio Euro and in row 2 with bank loan rates on loans in an amount over 1 Mio Euro; both rows are for Germany. Rows 3 and 4 are estimated with both the bank loan rate and the corporate bond yield in one model for the United States and Germany, respectively. The latter model includes two government bond yields of different maturity. The sample period is from 2003:M1–2016:M6. The black solid line depicts the point estimate, the shaded areas represent the 95% confidence intervals based on 5,000 bootstrap replications.

Figure 6: Robustness III: Impulse Responses to Uncertainty Shock with Costs and Volumes of External Financing for the United States and Germany from a Bayesian VAR

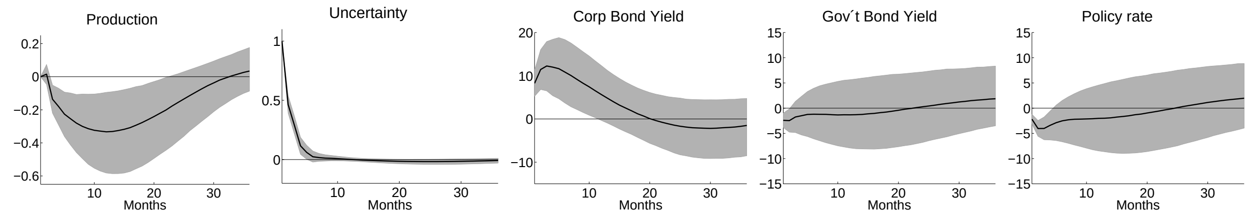


Notes: Effects of a unit shock to the standardized uncertainty series $FDISP^{US}$ and $FDISP^{GER}$, respectively. Uncertainty is expressed in unit values, loan and bond volumes are expressed in standard deviations, while all other variables are expressed in basis points. Uncertainty is ordered first in a recursive identification. The model for the Unites States is at a quarterly frequency with a sample period from 2003:Q1–2016:Q2, that for Germany is at a monthly frequency with a sample period from 2003:M1–2016:M6. Both models are estimated with Bayesian techniques. The black solid lines depict the median responses, the shaded areas represent 68% error bands.

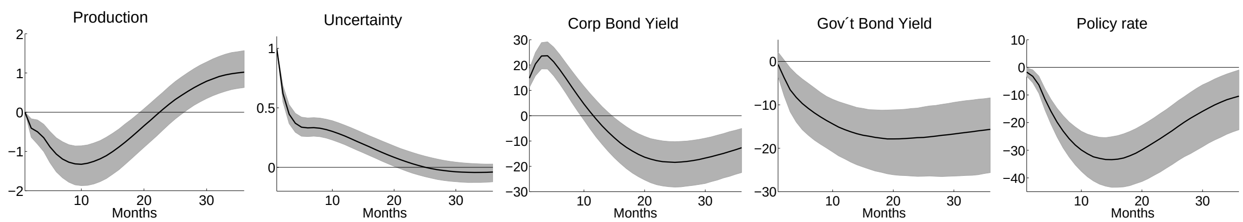
Figure 7: Robustness IV: Impulse Responses to Uncertainty Shock with Five Variables for the United States and Germany from a Bayesian VAR

With Corporate Bond Yields

US

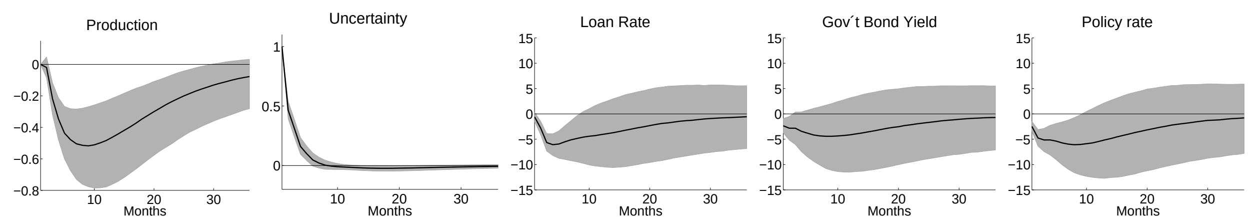


GER

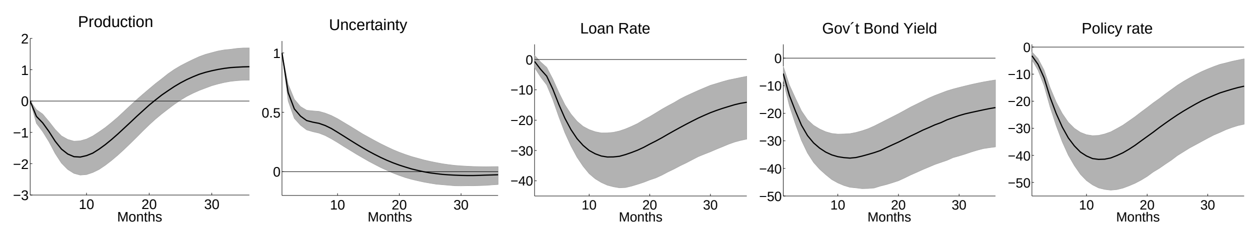


With Bank Loan Rates

US

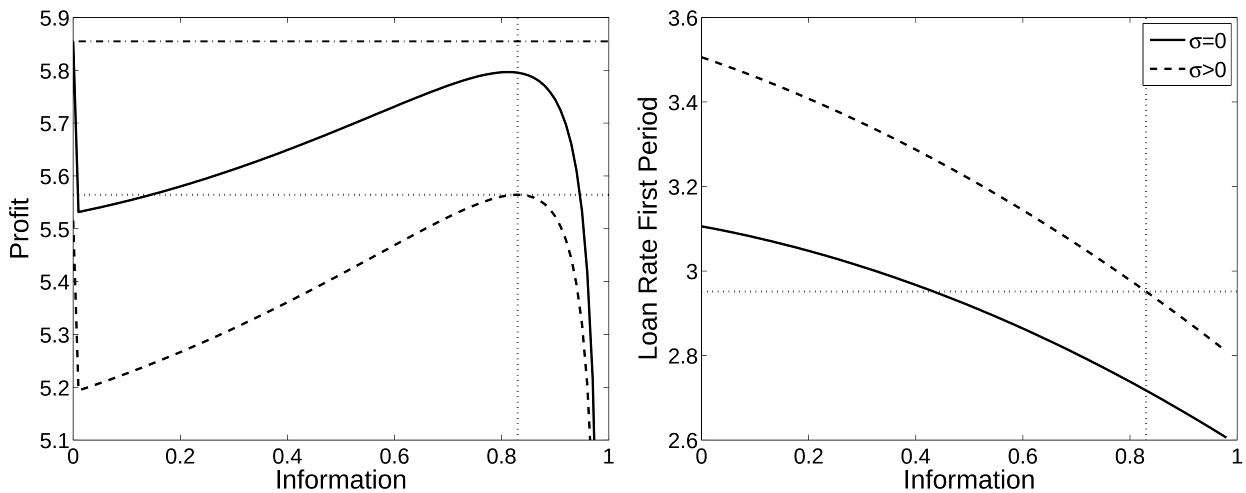


GER



Notes: Effects of a unit shock to the standardized uncertainty series $FDISP^{US}$ and $FDISP^{GER}$, respectively. Uncertainty is expressed in unit values, production is expressed in percent, while all other variables are expressed in basis points. Monthly Bayesian VARs are estimated with five variables. Uncertainty is ordered second after the activity variable in a recursive identification. The responses in rows 1 and 2 are estimated with corporate bond yields, those in rows 3 and 4 with bank loan rates. The sample period is from 2003:M1–2016:M6. The black solid lines depict the median responses, the shaded areas represent 68% error bands.

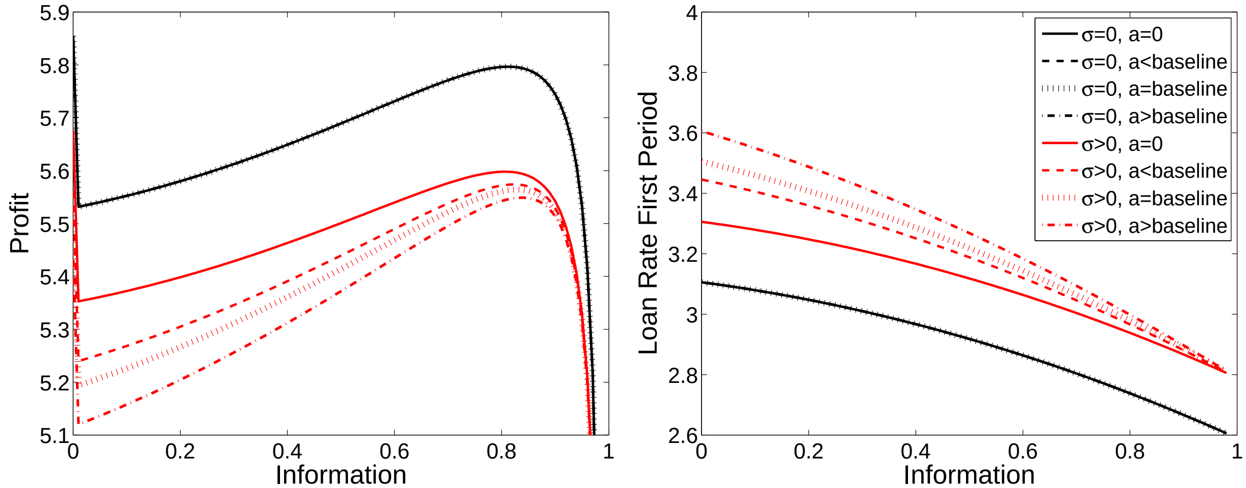
Figure 8: Baseline Results



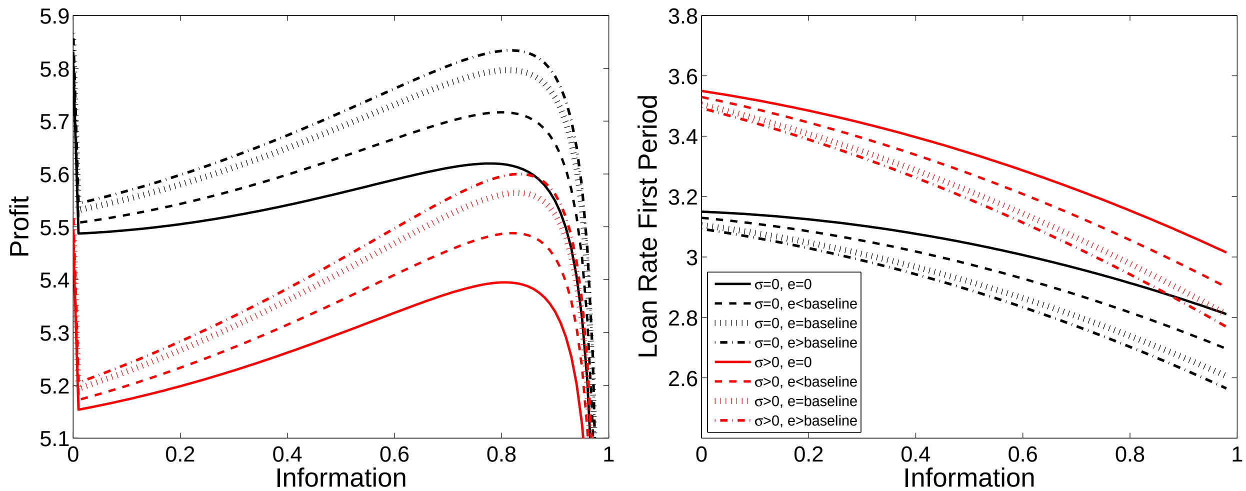
Notes: The left panel depicts the evolution of profits as market information increases, the right panel shows the reaction of loan rates as market information increases. The solid line is computed with no risk, $\sigma = 0$, the dashed line with elevated risk, $\sigma > 0$. In the left panel, the maximum possible profits are indicated by the horizontal dashed dotted line when $\sigma = 0$ and by the horizontal dotted line when $\sigma > 0$. The vertical dotted lines in both panels denote the optimal amount of information when $\sigma > 0$. In the right panel, the horizontal dotted line indicates the optimal lending rate when $\sigma > 0$.

Figure 9: Robustness (1)

Ambiguity a



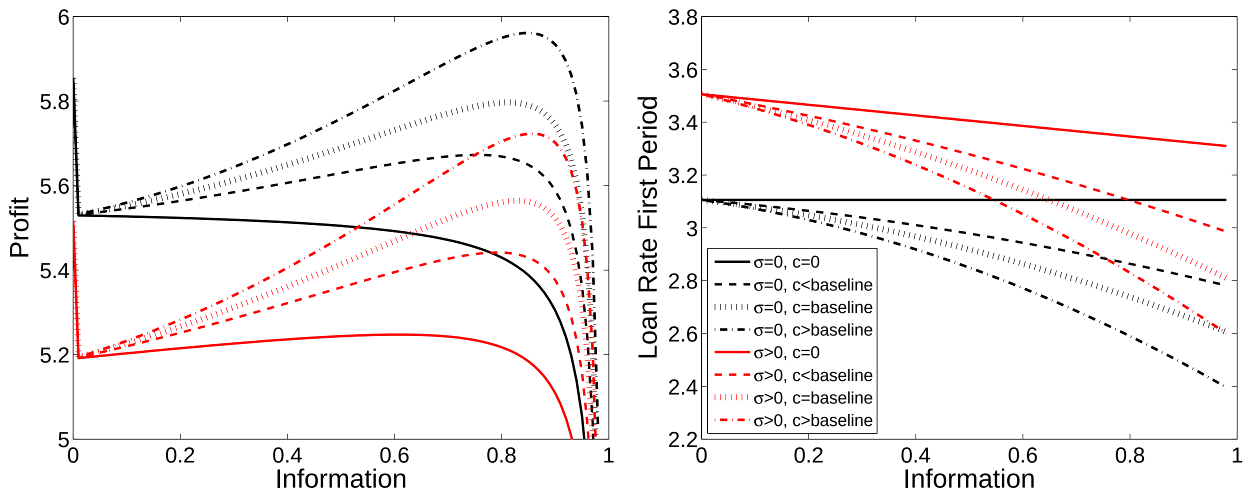
Markup Due to Private Information e



Notes: The left panels depict the evolution of profits as market information increases, the right panels show the reaction of loan rates as market information increases. The black lines are computed with no risk, $\sigma = 0$, the red lines with elevated risk, $\sigma > 0$. The dotted lines represent the results with the baseline parametrization.

Figure 10: Robustness (2)

Markup Due to Market Information c



Notes: The left panel depicts the evolution of profits as market information increases, the right panel shows the reaction of loan rates as market information increases. The black lines are computed with no risk, $\sigma = 0$, the red lines with elevated risk, $\sigma > 0$. The dotted lines represent the results with the baseline parametrization.

Table

Table 1: Parameter Values

Parameter	Value	Description
$\bar{x}$	10	Upper Bound of Interval
$\underline{x}$	2.9	Lower Bound of Interval
$\bar{\mu}$	6.85	Monitoring Cost
e	0.085	Markup Due to Private Information Acquisition
a	1	Ambiguity
σ	0 or 0.2	Risk
c	2	Markup Due to Market Information
$K_{I>0}$	0.3	Fixed Cost of Information Acquisition
κ	0.025	Adjustment Cost of Information Acquisition
Values for Sensitivity Analyses		
a	0 / 0.7 / 1.0 / 1.5	Ambiguity
e	0 / 0.05 / 0.085 / 0.1	Markup Due to Private Information
c	0 / 1.5 / 2.0 / 2.5	Markup Due to Market Information

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Appendix

A Construction of Idiosyncratic Uncertainty Proxies

For Germany, I use manufacturing firms' responses to the monthly IFO Business Climate Survey (IFO-BSC). The Business Climate Index, which is based on this survey, is a much-followed leading indicator for economic activity in Germany. I focus on the following question from the survey:

> Expectations for the next three months: Our domestic production activities with respect to product X will (without taking into account differences in the length of months or seasonal fluctuations) increase, roughly stay the same, decrease.

Exp_t^+ is defined as the fraction of firms that expect at time t an increase in production activity and Exp_t^- as the fraction of firms that expect a decrease. Uncertainty is proxied by the cross-sectional dispersion of expectations about future production:

$$FDISP_t^{GER} = \sqrt{Exp_t^+ + Exp_t^- - (Exp_t^+ - Exp_t^-)^2}\ , \tag{11}$$

For the United States, I use data from the Business Outlook Survey (BOS), which is conducted on a monthly basis by the Federal Reserve Bank of Philadelphia and surveys large manufacturing firms in the Third Fed district.[26] I focus on the following question from the survey:

> General Business Conditions: What is your evaluation of the level of general business activity six months from now vs. [Current Month]: decrease, no change, increase?

In contrast to what is available for the IFO-BSC, I do not have access to detailed micro data from the BOS. However, the net balances Exp_t^+ and Exp_t^- are available. Using Equation (11), I calculate the U.S. uncertainty proxy, $FDISP^{US}$, as the dispersion of firms' forecasts about the general business outlook.

[26]Bachmann et al. (2013) argue that the BOS is representative of the entire United States. They find that economic activity as measured in the BOS is highly correlated with (national) manufacturing industrial production.

B Data

Table 2: Data Sources: Germany

Variable	Description	Source
$FDISP^{GER}$	Cross-sectional standard deviation of production expectations, manufacturing firms, seasonally adjusted with X-12 and standardized	IFO & own calculations
Production	Manufacturing sector, seasonally adjusted, constant prices	Federal Statistical Office
Corp bond yield	Yields on fully taxed bonds outstanding, issued by non-financial corporations, average maturity of 6 years	Bundesbank
Corp bond volume	Securities other than shares, excluding financial derivatives, net issues (flows), non-financial corporations, 12-month cumulative values and standardized	ECB Statistical Data Warehouse
Loan rate	Loan rate for loans other than revolving loans and overdrafts, non-financial corporations, newly issued, up to 1 year, in % p.a.	Bundesbank
Loan rate <1 Mio	Loan rate for loans other than revolving loans and overdrafts, non-financial corporations, newly issued, up to 1 year, up to 1 Mio, in % p.a.	Bundesbank
Loan rate >1 Mio	Loan rate for loans other than revolving loans and overdrafts, non-financial corporations, newly issued, up to 1 year, over 1 Mio, in % p.a.	Bundesbank
Loan volume	Loans other than revolving loans and overdrafts, non-financial corporations, newly issued, up to 1 year, standardized	Bundesbank
Government bond yield 1y	1 to 2 years of maturity, in % p.a.	Bundesbank
Government bond yield 6y	5 to 6 years of maturity, in % p.a.	Bundesbank
EONIA	Day-to-day money market rate, monthly average, in % p.a.	Bundesbank

Table 3: Data Sources: United States

Variable	Description	Source
$FDISP^{US}$	Cross-sectional standard deviation of business expectations, manufacturing firms, third FED district, seasonally adjusted with X-12 and standardized	BOS & own calculations
Production	Manufacturing sector, seasonally adjusted, constant prices	Federal Reserve Board
Corporate bond yield 1–3y	Effective yield of investment-grade-rated corporate debt with maturity between 1 and 3 years	Merrill Lynch
Corporate bond yield 30y	Effective yield of Baa-rated corporate debt with maturity of 30 years	Moody's
Corp bond volume	Corporate bonds, flows from financial accounts, nonfinancial corporate business, 4-quarters cumulative values and standardized	Federal Reserve Board
Loan rate 1y	Charged by commercial banks for all new commercial and industrial loans, up to 1 year, interpolated from quarterly to monthly frequency*, shifted**, in % p.a.	Federal Reserve Board
Loan rate 1y/min	Charged by commercial banks for all new commercial and industrial loans, up to 1 year, with minimal risk, interpolated from quarterly to monthly frequency*, shifted**, in % p.a.	Federal Reserve Board
Loan rate 1y/low	Charged by commercial banks for all new commercial and industrial loans, up to 1 year, with low risk, interpolated from quarterly to monthly frequency*, shifted**, in % p.a.	Federal Reserve Board
Loan rate 1y/mod	Charged by commercial banks for all new commercial and industrial loans, up to 1 year, with moderate risk, interpolated from quarterly to monthly frequency*, shifted**, in % p.a.	Federal Reserve Board
Loan rate 1y/acc	Charged by commercial banks for all new commercial and industrial loans, up to 1 year, with other risk (acceptable), interpolated from quarterly to monthly frequency*, shifted**, in % p.a.	Federal Reserve Board
Loan volume	Newly issued commercial and industrial loans, up to 1 year, standardized	Federal Reserve Board
Prime rate	Charged by commercial banks, used to price short-term business loans, in % p.a.	Federal Reserve Board
Government bond yield 30y	30-year treasury bond yield, in months where the 30-year treasury bond was missing the 20-year treasury bond was used, in % p.a.	Federal Reserve Board
Government bond yield 1y	1-year treasury bond yield, in % p.a.	Federal Reserve Board
Government bond yield 3y	3-year treasury bond yield, in % p.a.	Federal Reserve Board
Federal Funds Rate	Fed Funds Effective Rate, in % p.a.	Federal Reserve Board

Notes: *: The series is interpolated with the Chow-Lin procedure using the prime rate as the monthly interpolator variable. **: The interpolated monthly series is shifted by one month, because the original quarterly data are collected during the middle month of each quarter.

C Adverse Selection, Moral Hazard, and Risk

This section analyzes whether a lower lending rate during periods of elevated risk could be due to problems of adverse selection or moral hazard. Banks may be reluctant to raise interest rates when risk increases because this may shift the composition of their loan portfolio towards borrowers with riskier projects (adverse selection) or because they fear that borrowers will switch to riskier projects (moral hazard).

C.1 Adverse Selection

This section shows that the presence of adverse selection implies higher lending rates when risk increases. The structure of the model is based on the Walsh (2003) version of the Stiglitz and Weiss (1981) model. Firms invest in projects that yield a return of $R+x^\sigma$ with probability $\frac{1}{2}$ and $R-x^\sigma$ with probability $\frac{1}{2}$. x^σ equals $x+\sigma$, where x denotes the normal riskiness of the project and σ is additional risk; the latter can be thought of as a risk shock that is observable by all agents. Projects are fully financed by bank loans L, on which the interest rate R^B is paid. Each project requires an investment of one unit; therefore, $L=1$. If the project yields the high return, $R+x^\sigma$, the loan is repaid and the firm receives $R+x^\sigma-R^B$. If the project yields the low return, $R-x^\sigma$, the borrower defaults and receives nothing; the bank receives the project return. The expected profit to a firm is:

$$E\pi^{Firm} = \frac{1}{2}\left[R+x^\sigma - R^B\right] \ ,$$

from which the threshold level $\hat{x}^\sigma$ can be derived at which $E\pi^{Firm}$ equals zero,

$$\hat{x}^\sigma = R^B - R \ .$$

The threshold increases in R^B. There are two types of borrowers, one with low-risk projects, $x^\sigma = x^\sigma_l$, and one with higher-risk investments, $x^\sigma = x^\sigma_h > x^\sigma_l$. Both types are equally likely. If the loan rate is small enough so that $\hat{x}^\sigma \leq x^\sigma_l < x^\sigma_h$, both groups of firms borrow from the bank. The bank return is:

$$E\pi^{Bank} = \frac{1}{2}\left[R^B + R\right] - \frac{1}{4}(x^\sigma_l + x^\sigma_h) \ ,$$

The bank return increases with R^B as long as the threshold level $\hat{x}^\sigma$ is smaller than x^σ_l. However, if the bank raises R^B by enough that the threshold level is above x^σ_l, all low-risk type borrowers stop borrowing. Therefore, if $x^\sigma_l \leq \hat{x}^\sigma \leq x^\sigma_h$, the bank return drops to

$$E\pi^{Bank} = \frac{1}{2}\left[R^B + R\right] - \frac{1}{2}x^\sigma_h \ .$$

The bank profit falls when the lending rate is

$$R^B_\sigma = x^\sigma_l + R \ , \tag{12}$$

because of the shift in the composition of the bank's loan portfolio toward borrowers with high-risk projects. Evaluating Equation (12) at $x^{\sigma=0}_l$ (when there is no additional risk) and, again, at $x^{\sigma>0}_l$ (when there is additional risk), gives

$$R^B_{\sigma=0} < R^B_{\sigma>0} \ .$$

If the lender cannot observe the borrower's risk type, it is optimal to increase the lending rate when there is additional risk because higher risk implies that borrowers gain on the upside, while having limited liability on the downside. Both x^σ_l and x^σ_h increase. A higher x^σ_l implies that the threshold value $\hat{x}^\sigma$ can also increase without a drop out of all borrowers with relatively low risk projects. A higher $\hat{x}^\sigma$ is associated with a higher lending rate.

C.2 Moral Hazard

This section shows that moral hazard implies higher loan rates when risk rises. The structure of the model is based on the Walsh (2003) version of the Stiglitz and Weiss (1981) model. A firm can either invest in project l, which yields a return of $R+x^\sigma_l$ with probability p_l and $R-x^\sigma_l$ with probability $1-p_l$ or it invests in project h with a yield of $R+x^\sigma_h$ with probability p_h and $R-x^\sigma_h$ with probability $1-p_h$. x^σ_i equals $x_i+\sigma$, where $i=(l,h)$ is the type of project risk, x denotes the normal riskiness of the project, and σ is additional risk; the latter can be thought of as a risk shock that is observable by all agents. Project h is riskier than l with $x^\sigma_h > x^\sigma_l$ and $p_l > p_h$. Projects are fully financed by bank loans L, on which the interest rate R^B is paid. Each project requires an investment of one unit; therefore, $L=1$. If either of the two projects yields a high return, $R+x^\sigma_i$, the loan is repaid and the firm receives $R+x^\sigma_i - R^B$. If project i yields a low return, $R-x^\sigma_i$, the borrower defaults and receives nothing; the bank receives the project return. Investing in project l, the firm can expect a profit of

$$E\pi^{Firm}_l = p_l\left[R + x^\sigma_l - R_B\right] \ ,$$

while the expected return from project h is

$$E\pi^{Firm}_h = p_h\left[R + x^\sigma_h - R_B\right] \ .$$

If the expected profits of the two projects are equal, $E\pi_l^{Firm} = E\pi_h^{Firm}$, the threshold value for the loan rate, $\hat{R}^B$, at which the firm is indecisive between the two projects, can be derived:

$$\hat{R}^B = \frac{p_l(R + x_l^\sigma) - p_h(R + x_h^\sigma)}{p_l - p_h} \ . \tag{13}$$

If the loan rate is below $\hat{R}^B$, the firm prefers the project with lower risk l, and the expected return to the bank is

$$E\pi_l^{Bank} = p_l \cdot R^B + (1 - p_l)(R - x_l^\sigma) \ .$$

If, instead, $R^B > \hat{R}^B$, the firm invests in the riskier project h. The bank's expected profit drops to

$$E\pi_h^{Bank} = p_h \cdot R^B + (1 - p_h)(R - x_h^\sigma) \ ,$$

because $E\pi_l^{Bank}(\hat{R}^B) > E\pi_h^{Bank}(\hat{R}^B)$.[27] Therefore, the bank has an incentive not to raise the loan rate above $\hat{R}^B$ given a level of risk σ. Evaluating Equation (13) at $x_l^{\sigma=0}$ (when there is no additional risk) and, again, at $x_l^{\sigma>0}$ (when there is additional risk) yields:

$$\hat{R}^B_{\sigma=0} < \hat{R}^B_{\sigma>0} \ ,$$

because $p_l > p_h$. If the bank cannot observe which of the projects the borrower chooses, it is still optimal to raise the loan rate when risk increases because all projects become riskier, and the borrower switches to the riskier project h only at a higher lending rate.

[27] This is because $x_h^\sigma(1 - 2p_h) - x_l^\sigma(1 - 2p_l) > 0$.

D Ex-Post Forecast Errors and Ambiguity

This section shows that the (ex-post) absolute forecast errors derived from the lowest possible dispersion, $\sigma(1-a)$, are higher than from the highest possible dispersion, $\sigma(1+a)$.

The forecast error, FE, equals $\pi - E[\pi]$, where π is the lender's realized profit and $E[\pi]$ is the expected profit. The realized profit depends on the true level of risk, σ, while the expected profit depends on $\sigma_a \in [\sigma(1-a), \sigma(1+a)]$. To compute the forecast error for the highest possible dispersion, FE_h, I use $\sigma_{a,h} = \sigma(1+a)$ and the associated loan rate, $R_h = \bar{x} - \bar{\mu} + \sigma_{a,h}$, which yields:

$$FE_h = \delta_1 - \frac{1}{z+2a\sigma} \cdot \alpha_1 + \delta_2 - \frac{1}{z+2a\sigma} \cdot \alpha_2 - \frac{1}{z+2a\sigma} \cdot (\alpha_3 + a \cdot \epsilon_1)$$

where

$$\begin{aligned}
z &= \bar{x} - \underline{x} + 2\sigma \\
\delta_1 &= \left\{ \frac{1}{2}(\bar{x})^2 + (\bar{\mu})^2 - \bar{x}\bar{\mu} \right\} \frac{1}{z} - \frac{1}{2}\sigma^2(1+a)^2 \frac{1}{z} \\
\delta_2 &= \frac{1}{z} \left\{ -\frac{1}{2}(\underline{x})^2 + [\bar{x} + \underline{x} - 2\bar{\mu} + \sigma(1+a)]\,\sigma - \frac{1}{2}\sigma^2 - \frac{1}{2}(\bar{\mu})^2 + \underline{x}\bar{\mu} \right\} \\
\alpha_1 &= \frac{1}{2}(\bar{x})^2 + (\bar{\mu})^2 - \frac{1}{2}\sigma^2(1+a)^2 - \bar{x}\bar{\mu} \\
\alpha_2 &= -\frac{1}{2}(\underline{x})^2 + \underline{x}\bar{\mu} - \frac{1}{2}(\bar{\mu})^2 \\
\alpha_3 &= \left(\bar{x} + \underline{x} - 2\bar{\mu} + \frac{1}{2}\sigma \right) \sigma \\
\epsilon_1 &= \left(\bar{x} + \underline{x} - 2\bar{\mu} + \frac{1}{2}\sigma(2+a) \right) \sigma \ .
\end{aligned}$$

The forecast error for the lowest possible dispersion, FE_l, depends on $\sigma_{a,l} = \sigma(1-a)$ and the associated loan rate, $R_l = \bar{x} - \bar{\mu} + \sigma_{a,l}$, which yields:

$$FE_l = \delta_1 - \frac{1}{z-2a\sigma} \cdot \alpha_1 + \delta_2 - \frac{1}{z-2a\sigma} \cdot \alpha_2 - \frac{1}{z-2a\sigma} \cdot (\alpha_3 - a \cdot \epsilon_2)$$

where

$$\epsilon_2 = \left(\bar{x} + \underline{x} - 2\bar{\mu} + \frac{1}{2}\sigma(2-a) \right) \sigma \ .$$

Taking the absolute values of the forecast errors, $\text{abs}(FE_l) = |FE_l|$ and $\text{abs}(FE_h) = |FE_h|$, I find that

$$\underbrace{\left| \frac{1}{z-2a\sigma} (\gamma_1 + \alpha\beta_2) \right|}_{\text{abs}(FE_l)} > \underbrace{\left| \frac{1}{z+2a\sigma} (\gamma_1 - \alpha\beta_2) \right|}_{\text{abs}(FE_h)}$$

where

$$\beta_2 = (\bar{x} + \underline{x} - 2\bar{\mu} + \sigma)\,\sigma \quad \text{and} \quad \gamma_1 = -\alpha_1 - \alpha_2 - \alpha_3 - \frac{1}{2}a^2\sigma^2 \ .$$