DEUTSCHE BUNDESBANK
EUROSYSTEM

Discussion Paper

Deutsche Bundesbank
No 32/2014

Pro-cyclical capital regulation and lending

Markus Behn
(Bonn University and Deutsche Bundesbank)

Rainer Haselmann
(Bonn University)

Paul Wachtel
(NYU Stern School of Business)

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

Internet http://www.bundesbank.de

ISBN 978–3–95729–080–9 (Printversion)
ISBN 978–3–95729–081–6 (Internetversion)

Non-technical summary

Research Question

The thrust of changes in bank capital regulation through the Basel Accords over the last 25 years has been to align capital requirements with bank asset risk. However, such regulation can have negative side effects. In a weak economy asset risk increases which in turn increases capital requirements. This might induce banks to reduce lending. The relationship between risk based capital charges and bank lending has been explored in the theoretical literature. However, there has been no prior empirical examination of the issue. In this paper we estimate the effect of risk based capital charges on bank lending and firms' access to funds when there is an exogenous shock to credit risk.

Contribution

We are the first to provide direct empirical estimates of how the pro-cyclicality inherent in the model-based approach to capital regulation affects the supply of loans to firms. The richness of our loan-level data set and the institutional details of the German Basel II introduction allow us to overcome several identification issues related to bank and firm heterogeneity. Our paper shows that a tightening of capital requirements caused by pro-cyclical regulation affected lending in Germany after the Lehman collapse and had severe consequences for firms' overall access to funds.

Results

We find that loans subject to model-based, time-varying capital charges were reduced by 3.5 percent more than loans under the traditional approach to capital regulation. Importantly, we show that the effects are not driven by changes in the demand for loans or differences between banks using the new approach and banks not using it. Several cross-sectional tests support our argumentation. Finally, the effect is even stronger when we examine aggregate firm borrowing, suggesting that the pro-cyclical effect of model-based capital charges is not offset by substitution to other banks which use the traditional approach.

Nichttechnische Zusammenfassung

Forschungsfrage

Ein Hauptziel der Bankenregulierung seit Einführung der Basel I-Richtlinien im Jahr 1988 ist eine stärkere Orientierung der Eigenkapitalanforderungen am tatsächlichen Risiko einer Bank. Eine solche Regulierung kann negative Nebeneffekte haben, da sich das tatsächliche Risiko einer Bank und damit die Eigenkapitalanforderungen an die Bank im Abschwung erhöhen werden. Als Folge könnten die Banken ihr Kreditangebot im Abschwung verknappen. Der Zusammenhang zwischen risikobasierter Eigenkapitalregulierung und der Kreditvergabe von Banken wurde zwar in der theoretischen Literatur diskutiert, bisher gibt es aber kein empirisches Papier das diesen Zusammenhang explizit untersucht. Im vorliegenden Forschungspapier analysieren wir die Auswirkungen modellbasierter Eigenkapitalregulierung auf die Kreditvergabe in einer Rezession.

Beitrag

Unsere Studie ist die erste, die den Effekt modellbasierter Eigenkapitalregulierung auf die Kreditvergabe der Banken sowie die Finanzierungsmöglichkeiten der Firmen direkt quantifizieren kann. Unsere umfangreiche Datenbank sowie verschiedene institutionelle Aspekte der Basel II Einführung in Deutschland erlauben es uns, Identifikationsprobleme in Bezug auf Bank- und Firmenheterogenität zu umgehen. Unser Papier weist eine signifikante Einschränkung der Kreditvergabe im Anschluss an den Zusammenbruch von Lehman Brothers im Herbst 2008 als Folge der prozyklischen Regulierung nach.

Ergebnisse

Unsere Schätzungen zeigen, dass Kredite, die den modellbasierten Ansatz verwenden, um 3.5 % stärker reduziert werden als Kredite, die den traditionellen Ansatz nutzen. Wir zeigen auch, dass dieser Effekt nicht von Änderungen in der Kreditnachfrage oder von generellen Unterschieden zwischen der Gruppe der IRB Banken und der Gruppe der Banken im Standardansatz getrieben wird. Verschiedene Querschnittsergebnisse stützen unsere Argumentation. Wir finden auch auf Firmenebene einen signifikanten Effekt: Firmen, die einen höheren Anteil ihrer Kredite als IRB Kredite beziehen, verzeichnen in der Krise einen stärkeren Rückgang der Gesamtkredite.

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Markus Behn
Bonn University
Deutsche Bundesbank

Rainer Haselmann
Bonn University

Paul Wachtel
NYU Stern School of Business

Abstract

We use a quasi-experimental research design to examine the effect of model-based capital regulation introduced under the Basel II agreement on the pro-cyclicality of bank lending and firms' access to funds during a recession. In response to an exogenous shock to credit risk in the German economy, loans subject to model-based, time-varying capital charges were reduced by 3.5 percent more than loans under the traditional approach to capital regulation. The effect is even stronger when we examine aggregate firm borrowing, suggesting that the pro-cyclical effect of model-based capital charges is not offset by substitution to other banks which use the traditional approach.

Keywords: capital regulation, credit crunch, financial crisis
JEL Classification: G01, G21, G28

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*Author's contact addresses: Markus Behn, Bonn University, Adenauerallee 24, 53113 Bonn, Germany, behn@uni-bonn.de and Deutsche Bundesbank, Wilhelm-Epstein-Str. 14, 60431 Frankfurt, Germany; Rainer Haselmann, Bonn University, Adenauerallee 24, 53113 Bonn, Germany, rainer.haselmann@uni-bonn.de; and Paul Wachtel, Stern School of Business, NYU, 44 W 4^{th} St, New York, NY 10012; E-mail: pwachtel@stern.nyu.edu. We thank Puriya Abbassi, Linda Allen, Tobias Berg, Claudia Buch, Valeriya Dinger, Iftekhar Hasan, Robert Hauswald, Martin Hellwig, Anil Kashyap, Michael Koetter, Steven Ongena, Andreas Pfingsten, Michael Roberts, Jean-Charles Rochet, Amit Seru, Javier Suarez, David Thesmar, Vikrant Vig, Dawid Zochowski, and seminar participants at Bonn University, Bank of Finland, Deutsche Bundesbank, University of Mainz, University of Münster, University of Zurich, the Bank for International Settlements RTF Workshop, the Bundesbank/DGF/IMF Conference, the Central Banking Workshop, the Dubrovnik Economic Conference, the German Finance Association Meeting, and the German Research Foundation SPP-1578 Workshop for their helpful comments. We are grateful to Deutsche Bundesbank, especially to Klaus Düllmann and Thomas Kick, for their generous support with the construction of the data set and deep insights regarding the German banking sector. Peik Achtert, Birgit Maletzke, Christoph Memmel, and Wolfram Ohletz provided us with valuable insights regarding the institutional details surrounding the introduction of asset-specific risk weights by German banks. The usual disclaimer on errors applies here as well.

1 Introduction

The determination of bank capital charges is one of the most important and controversial topics in bank regulation.[1] One of the main goals in recent decades—starting with the Basel I agreement in 1988—was to align capital charges with the risk of bank assets. Basel II made an important step in this direction by introducing capital charges for individual loans that depend on model-based risk estimates. More than 100 countries have implemented the agreement (see Financial Stability Institute 2010) and many of the world's larger banks are now using their internal rating models to determine capital charges for individual credit risks.

There has long been a concern that linking capital charges to asset risk may exacerbate business cycle fluctuations (see Daníelsson, Embrechts, Goodhart, Keating, Muennich, Renault, and Shin 2001, Kashyap and Stein 2004, Repullo and Suarez 2012). Specifically, capital requirements will increase in a downturn if measures of asset risk are responsive to economic conditions; at the same time bank capital is likely to be eroded by loan write-offs. Capital constrained banks that are unable or unwilling to raise new equity in bad times will be forced to deleverage by reducing lending, hence exacerbating the initial downturn. In this paper, we use data from the German credit register to identify the effect of asset-specific, risk-based capital charges on bank lending behavior and on the aggregate ability of firms to borrow when there is an exogenous real sector shock. The effects on firms access to credit are particularly important to assess the consequences of pro-cyclical model-based capital regulation for the real sector.[2]

While the pro-cyclicality of bank lending under Basel II has been widely discussed,[3] four issues make identifying the empirical effects on lending a difficult task. First, a bank's risk assessment and its lending decision for a specific borrower are likely to be jointly determined, which means that the relationship between risk estimates and lending adjustments suffers from endogeneity. Second, economic downturns are likely to affect both a firm's loan demand and the lender's evaluation of its credit risk. Therefore, it is essential to disentangle a shift in a firm's loan demand from a shift in loan supply. Third, a downturn might affect the larger banks which are more likely to use risk models to determine capital charges differently than the smaller banks which retain the traditional approach to capital regulation. Thus, it can be difficult to determine whether a change in bank lending is driven by pro-cyclical capital regulation, or the way in which the bank is affected by a recession shock. Fourth, micro-level data on loan amounts combined with information on the regulatory approach used by the bank to determine capital charges for the respective loans are difficult to obtain.

We address these issues by examining changes in bank lending in Germany around

[1]See Peltzman (1970), Koehn and Santomero (1980), Kim and Santomero (1988), Blum and Hellwig (1995), Diamond and Rajan (2000, 2001), Morrison and White (2005), or Acharya (2009). An early review of the literature is provided by Bhattacharya, Boot, and Thakor (1998).

[2]Terminology is as follows: capital charges are counter-cyclical, if they increase during an economic downturn. If banks react by cutting back lending, then lending and credit availability are pro-cyclical and amplify the business cycle.

[3]See Borio, Furfine, and Lowe (2001), Lowe (2002), Goodhart, Hofman, and Segoviano (2004), Gordy and Howells (2006), Rochet (2008), Repullo, Saurina, and Trucharte (2010), or Gersbach and Rochet (2013). Brunnermeier (2009) and Hellwig (2009) discuss how pro-cyclical features of the regulation contributed to the financial crisis.

the credit risk shock that followed the failure of Lehman Brothers in September 2008. Immediately after Lehman, the German economy entered a recession, associated with a steep and abrupt decline in real sector expectations. Contemporaneous newspaper articles document the importance of the credit risk shock and illustrate that the contraction came unexpectedly for the majority of analysts and economists.[4] As credit risk exogenously increased banks had to adjust their internal risk estimates, implying an increase in capital charges for loans under model-based capital regulation. In contrast, capital charges for loans under the traditional approach to capital regulation were unaffected by the credit risk shock as they did not depend on economic conditions.

At the time of the credit risk shock, German banks were in the midst of implementing the Basel II regulations. They were allowed to choose between the model-based approach (termed internal ratings-based, or IRB) and the more traditional or standard approach (SA) with fixed risk weights. At those banks that opted for model-based regulation (IRB banks), the approach was being phased in over time. Thus, in September 2008, IRB banks were using the IRB approach for some of their loan portfolios while other portfolios were still subject to SA. Since German firms typically have multiple banking relationships, many firms found themselves in the IRB pool of one bank and in the SA pool of another IRB bank. This institutional setup allows us to systematically control for both bank and firm heterogeneity. Specifically, we can test whether the same firm—borrowing from two different IRB banks—obtains relatively less credit from the bank where the firm is in the IRB pool following the credit risk shock, as compared to the bank where the firm is in the SA pool. Importantly, we are able to hold constant firm-specific determinants of loan demand and bank-specific determinants of loan supply (compare with Khwaja and Mian 2008, Jiménez, Ongena, Peydró, and Saurina 2014). Our study benefits from the extensive information that is available in the German credit register, including loan-level information on the regulatory approach and the internal risk estimate of the bank.

We find that the approach used to determine capital charges has a strong and economically meaningful impact on the cyclicality of lending. Our estimates indicate that capital requirements for loans under IRB rose by about 0.5 percentage points over the credit risk shock, which is large since the regulatory minimum capital requirement is 8 percent of risk-weighted assets (RWA). As a consequence, banks using IRB reduced loans to the same firm by 2.1 to 3.9 percentage points more in response to the shock when capital charges for the loan were based on internal ratings (IRB) instead of fixed risk weights (SA).

Identification in this test rests on the assumption that the selection of IRB loans within IRB banks is not systematically related to the adjustment of loans in response to the credit risk shock. Whether a specific loan portfolio had been shifted to IRB prior to the shock is mainly determined by the size of the portfolio. Banks first applied IRB to loan portfolios for which they had sufficient data to calibrate a meaningful risk model. We find that the size of a portfolio has a positive influence on the adjustment of loans over the shock, which means that any bias from selection is likely to work against our findings.

To mitigate remaining concerns, we exploit another institutional feature of the Basel II framework. The regulation provides a capital charge discount for loans to firms with a

[4] See, e.g., *F.A.Z.*, December 23, 2008, "Economists failed in predicting the crash". Evidence from newspaper articles is summarized in Appendix TableA.1.

turnover less than € 50 million. Consequently, the impact of the credit risk shock on capital charges for IRB loans varies with the size of the firm. A given increase in risk parameters induced a smaller increase in capital charges for loans to small firms that benefited from the discount. Controlling for any potential difference between the SA and IRB pool of a specific bank, we find that the relative reduction of IRB loans is 1.3 to 3.2 percentage points stronger for firms with a turnover of € 50 million as compared with firms with a turnover of € 25 million. This finding suggests a strong influence of the regulatory treatment on the adjustment of loans over the shock, while it cannot be due to the assignment of loans to the IRB group.

Several cross-sectional tests further strengthen our results. IRB banks with a low equity ratio had a small buffer to absorb increases in capital charges and consequently reduced their IRB loans relatively more following the credit risk shock. Further, the IRB effect is more pronounced for less profitable firms which are likely to be more affected by the credit risk shock, and for firms to which IRB banks have a relatively large exposure. Taken together, these findings suggest that the credit risk shock forced banks to deleverage in order to fulfill the higher capital requirements induced by model-based regulation.

In a final step we examine whether the introduction of risk-based capital regulation had pro-cyclical effects on the aggregate availability of bank credit to firms. To account for differences in loan demand among firms borrowing from different types of banks, we focus on variation in the share of a firm's loans obtained from IRB banks that are subject to the IRB approach. Interestingly, we find that pro-cyclical effects are even stronger at the firm level. A firm with 82 percent IRB loans (75^{th} percentile) prior to the shock experiences a reduction in aggregate lending that is 3.0 to 4.6 percentage points larger than the reduction for a firm with 43 percent IRB loans (25^{th} percentile). This result is consistent with the earlier finding that banks cut particularly those IRB loans to which they have a high exposure in response to the credit risk shock. Further, during economic downturns, it seems to be difficult for firms to offset reductions in lending from one bank by increasing borrowing from other banks. This suggests that microprudential regulation can have sizeable consequences for the real sector during economic downturns. We find little evidence that firms that had more IRB loans experienced greater increases in capital costs, which suggests that banks using IRB adjusted loan quantities rather than loan conditions (i.e., prices) in reaction to the credit risk shock.

We conduct several robustness tests to assess the possibility that confounding shocks around our event are responsible for parts of our findings. For example, we use placebo tests to check for potential pre-trends and do not find any significant differences in the adjustment of IRB and SA loans prior to the credit risk shock in 2008Q3. In some sense, our findings are conditional on the banking sector finding itself in a crisis period. Although our identification strategy allows us to address the fact that individual banks have been heterogeneously affected by the financial crisis, it is possible that differences in the adjustment of IRB and SA loans would have been less pronounced if banks had not been affected by the global financial crisis and therefore had had more capital available. Since real sector and financial crises tend to go hand-in-hand, we do not think that this observation makes the findings of our paper less interesting.

Our paper is the first to provide direct empirical estimates of how the pro-cyclicality inherent in the model-based approach to capital regulation affects the supply of loans to firms. Previous studies of the pro-cyclicality of regulation used simulation models[5] or analyzed the effects of business cycles on aggregate buffers.[6] Our findings confirm the warnings regarding Basel II capital regulation by policy analysts such as Borio et al. (2001), Goodhart et al. (2004), and Gordy and Howells (2006).

Further, we add to the literature that analyzes the impact of bank liquidity or capital shocks on loan supply (Bernanke 1983, Bernanke, Lown, and Friedman 1991, Kashyap and Stein 2000). Our findings are consistent with earlier research indicating that poorly capitalized banks reduce lending during recessions (Gambacorta and Mistrulli 2004), and that loan supply shocks have a negative effect on real economic activity (Peek and Rosengren 1997, 2000).

Most closely related to our own paper is the work by Jiménez, Ongena, Peydró, and Saurina (2013), who examine the effect of dynamic provisioning rules in Spain and find that lowering capital requirements when economic conditions deteriorate helps banks to maintain their supply of credit. Other evidence suggests that increases in capital requirements induce reductions in lending (Thakor 1996, Aiyar, Calomiris, and Wiedalek 2014). Ivashina and Scharfstein (2010), Puri, Rocholl, and Steffen (2011), Kahle and Stulz (2013), Iyer, Da-Rocha-Lopes, Peydró, and Schoar (2014), and Paravisini, Rappoport, Schnabl, and Wolfenzon (2014) document the extent of the credit crunch during the recent crisis. Our paper combines these different strands of the literature by showing that a tightening of capital requirements caused by pro-cyclical regulation affected lending in Germany after the Lehman collapse and had severe consequences for firms' overall access to funds.

Our findings illustrate how microprudential and macroprudential goals of banking sector regulation might conflict with one another.[7] On the one hand, the reduction in lending we document is due to capital charges that are based on improved evaluations of credit risk. In terms of safety of the individual bank, it might make sense to extend fewer loans when economic conditions deteriorate. Following this logic, Repullo and Suarez (2012) suggest that pro-cyclical side effects of Basel II may have a payoff in the long-term solvency of the banking system. On the other hand, as banks simultaneously restrain their lending, firms' access to funds becomes restricted which might negatively affect investment expenditure and exacerbate the cyclical shock. In order to evaluate the welfare effects of pro-cyclical capital regulation one would have to evaluate both its impact on the long-term safety of the banking sector and its effect on credit supply in economic downturns. While we cannot make a statement on the former, our findings help to quantify the latter.

Section 2 describes the institutional details around the introduction of Basel II in Germany and our data. Section 3 outlines our empirical strategy. Sections 4, 5 and 6 present the results. Section 7 offers our conclusions.

[5]See Carling, Jacobson, Lindé, and Roszbach (2002), Corcóstegui, González-Mosquera, Marcelo, and Trucharte (2002), Lowe and Segoviano (2002), Kashyap and Stein (2004), Saurina and Trucharte (2007), Francis and Osborne (2009), Andersen (2011).

[6]See Ayuso, Pérez, and Saurina (2004), Lindquist (2004), Jokipii and Milne (2008).

[7]See Galati and Moessner (2013) for a survey of the literature on macroprudential regulation. Recent academic contributions include Kashyap, Rajan, and Stein (2008), Brunnermeier, Goodhart, Persaud, Crockett, and Shin (2009), Hellwig (2010), Hanson, Kashyap, and Stein (2011), Acharya, Mehran, Schuermann, and Thakor (2012), and Acharya, Engle, and Pierret (2014).

2 Institutional background and data

The section begins with an explanation of the determination of capital charges in the Basel II agreement and the arrangements for its introduction in Germany. We then describe our event, a sudden change in expectations concerning the future performance of the German economy in the third quarter of 2008 that occurred as a consequence of the turmoil following the Lehman bankruptcy. Finally, we outline our underlying data set from the German credit register of Deutsche Bundesbank and present descriptive statistics.

2.1 Introduction of risk-weighted capital charges

The original Basel agreement (Basel I) introduced risk-based capital charges by assigning each bank asset to one of several risk buckets that received different risk weights (e.g., all corporate loans had the same risk weight of 100 percent). Regulatory capital requirements were defined in terms of risk-weighted assets, the amount of each asset multiplied by its risk weight. A drawback of this framework was that banks had an incentive to hold the riskiest assets within each risk bucket, as these provided the highest yield while being subject to the same capital charges as less risky assets in the bucket. Therefore, an important motive for the introduction of Basel II capital standards was the desire to establish a stronger link between capital charges and the actual risk of each asset.

Under Basel II, banks are allowed to choose among two broad methodologies to calculate their capital charges for credit risk.[8] First, the standard approach (SA) is similar to the old Basel I framework and automatically assigns a fixed risk weight of 100 percent to the uncollateralized part of corporate loans if the borrower has no external rating.[9] Second, banks can opt for the internal ratings-based (IRB) approach that relies on the banks' own estimates of the risk associated with a loan. IRB requires the estimation of four parameters to determine the risk weight for a loan: the probability of default (PD), the loss given default, exposure at default, and the effective maturity of the loan. The higher the estimate for any of these parameters, the higher the risk weight that is attributed to the loan.[10] For our analysis the crucial issue is that capital charges are endogenous to credit risk with IRB but not with SA. The internal risk models used by German banks estimate PDs continuously, so PDs are likely to increase during an economic downturn, implying higher capital charges if the bank is using IRB. In contrast, capital charges for loans under SA are determined when the loan is made and do not change.

[8] For a description of the Basel agreements see Basel Committee on Banking Supervision (1988), Basel Committee on Banking Supervision (1999), and Basel Committee on Banking Supervision (2006).

[9] If a firm's debt is rated by an external agency, the rating can be used to determine capital charges for loans. In Germany, very few firms have external corporate bond ratings (0.1 percent of the firms in our data have external ratings). We exclude loans to these firms from our analysis. In unreported regressions we find that our main result is less pronounced in this subsample, maybe because external ratings also change over the business cycle (although they tend to be more sticky than internal ratings, see Borio and Zhu 2012). Results for these tests are available upon request.

[10] In the advanced internal ratings-based approach, the bank provides estimates for all four parameters, while in the basic internal ratings-based approach the bank estimates only the PD, and standard values are assumed for the other parameters. We do not distinguish between the advanced and basic internal ratings-based approaches in our empirical analysis, because the risk weight depends on the loan's PD in both cases.

Since the introduction of the IRB approach involves substantial administrative costs, it was only adopted by the larger banks that could benefit from scale economies. These banks have an incentive to become IRB institutions because capital requirements are substantially lower under IRB than under SA. In order to deal with the operational complexity of introducing new rating models, banks that opted for IRB did not apply the new approach to all loans at once; rather, they agreed on a gradual implementation plan with the regulator. The implementation plan specifies an order according to which IRB is applied to the bank's loan portfolios (which are generally loans to a specific business unit). As the calibration of a meaningful PD model requires sufficient data on past loan performance, banks typically started with loan portfolios in business units where they were relatively active (see Section 3.1).

The introduction of IRB is closely monitored by the regulator. Each model has to be approved prior to its introduction and models are validated at least once a year. Once a rating model has been put in place for a specific portfolio, it is used to determine the capital charges for all new and existing loans. Thus, loans in a portfolio are shifted all at once, so that it is not possible for the bank to strategically shift individual loans from one approach to the other. This also implies that all of a bank's loans to a given firm are classified under the same regulatory approach at any point in time. The German banks that adopted IRB submitted their implementation plans to the regulator in 2006. Hence, they were not able to react to the financial crisis by changing the order of loan portfolios that were transferred to IRB or by applying the standard approach to IRB portfolios after loan PDs deteriorated. At the outset of our data period, 2008Q1, the IRB phase-in of portfolios was underway. Thus, capital charges for IRB banks were determined by the internal ratings-based approach for some loan portfolios and by the standard approach for others. We exploit this within-bank variation for our identification strategy as explained in Section 3.

2.2 The Lehman event as an exogenous real sector shock

As explained in the introduction, it is difficult to examine the relationship between changes in the PD and changes in lending, as these variables are endogenous. To circumvent this issue, we exploit the Lehman collapse which was an event that exogenously increased credit risk in the German economy. That is, we examine the impact of the credit risk shock induced by the real sector downturn that followed the Lehman collapse.

Newspaper articles from both the German and the international press document the importance of the credit risk shock and show that real sector optimism persisted in 2008 and then changed drastically after the Lehman bankruptcy in mid-September. E.g., in May *Die Welt* (May 22, 2008) reported that "the German economy is not affected by the turbulence on financial markets and the crisis in the US" and went on to cite expert opinion that "the German economy rests on solid fundamentals." The tone changed within a few weeks of the Lehman bankruptcy. *Handelsblatt* (October 14, 2008) quotes expert opinion that "the German economy is now in a downward spiral [...] and [there will be an] increase in corporate bankruptcies." By the end of the year *F.A.Z.* (December 23, 2008) reported that "Germany will face the worst economic crisis in 50 years." Importantly, the economic contraction came unexpectedly for the majority of economists as documented by the revision of almost all forecast indicators around this time (see, e.g., *F.A.Z.*, December

23, 2008, "Economists failed in predicting the crash"). Relevant newspaper articles are summarized in Appendix TableA.1.

The decline in real sector expectations at the end of 2008 was both steep and abrupt. Real GDP in Germany declined slightly in the second and third quarters but took an unprecedentedly large plunge in the two quarters following the Lehman collapse. It fell by 7.7 percent at an annual rate in the last quarter of 2008 and by 15.5 percent in the following quarter. It took almost three years for real GDP to regain its peak level (see Figure 1, Panel A). Changed expectations regarding future economic performance led to an exogenous increase in estimated probabilities of default, which is precisely the event we are looking for, as it induces variation in changes in capital charges between loans that are subject to IRB and loans that are subject to SA.

The impact of the credit risk shock on aggregate bank lending in Germany is shown in Figure 1, Panel B. German banks expanded their lending until the end of 2008 even as economies around the world slowed down and the financial crisis had started. Only after the third quarter of 2008 (our event date) did lending begin to decline.

The relationship between the decline in aggregate lending and model-based capital regulation is illustrated in Panel A of Figure 2. It shows aggregate IRB loans reported in the German credit register and the associated risk-weighted assets (RWAs). The aggregate volume of IRB loans drops sharply after the shock as banks reduce their IRB lending exposure. The right graph shows the ratio of total RWAs to total IRB loans; the ratio increases sharply until the second quarter of 2009 then declines for about a year when it levels off.

The figure shows that banks had to hold more capital for the same amount of IRB loans following the credit risk shock. This pattern illustrates the pro-cyclical effect of capital charges: during a recession banks reduce lending in order to keep capital charges constant. The decline in the ratio of RWAs to loans occurred because banks reduced those loans whose risk weights increased most after the shock. We provide evidence for this interpretation in Panel B of Figure 2, which shows total RWAs under the assumption that banks do not adjust the quantity of their loans. Specifically, we calculate a hypothetical series for RWAs by multiplying the observed risk weight for each loan in each period by the loan amount in 2008Q3, and then aggregate these amounts in each quarter.[11] The right graph of Panel B depicts the ratio of the hypothetical RWAs series to the total amount of loans in 2008Q3. It shows that if banks had not adjusted their IRB loans following the credit risk shock, the RWAs to loans ratio would have continued to increase throughout the period. Figure 2 offers strong evidence of a pro-cyclical effect of risk-weighted capital charges on bank loan supply.

2.3 Data and descriptive statistics

Our principal source of data is the German credit register compiled by Deutsche Bundesbank. The central bank collects data each quarter on all outstanding loans of at least € 1.5 million. A distinct feature of the Bundesbank credit register as compared with other credit registers is that banks have to report the regulatory approach used to determine

[11] Since we cannot observe risk weights for loans that were canceled or matured before the end of our sample period, we consider only loans that existed throughout the entire sample period. The exclusion of other loans is likely to bias against finding an increase in the RWAs to loans ratio.

capital charges for the loan as well as the corresponding credit risk estimates (i.e., PDs). The dataset also includes information on the lender's and the borrower's identity, the amount of the loan outstanding, risk-weighted assets corresponding to the loan, and the amount of collateral provided by the borrower. We supplement the loan data with annual information on the lenders from bank balance sheets obtained from the Bundesbank's BAKIS database.

Our sample includes 1,825 banks. We restrict the analysis to those commercial loans for which we are able to determine the regulatory approach used at the beginning of our sample period in 2008.[12] We consider a loan to be an IRB loan if the bank adopted the approach for the loan no later than the second quarter of 2008. Since the implementation of the internal ratings-based approach extends over several years, some loans that we classify as SA are moved to IRB during our sample period. We address this issue in Section 6.3. As shown in Panel A of Table 1, there are 1,784 banks using SA and 41 banks that have adopted IRB. On average, IRB banks had adopted the new approach for 62 percent of their loans when our sample period starts (*Share IRB*). The IRB banks are much larger, have lower equity ratios and about the same ROA as institutions using the SA.

Descriptive statistics for the loan-level data are shown in Panel B of Table 1. There are 182,966 loans to 107,025 distinct firms for the period from the first quarter of 2008 through the third quarter of 2011. Descriptive statistics are shown separately for the three types of loans in our sample: (1) loans provided by SA banks; (2) loans provided by IRB banks that are still subject to SA; and (3) loans provided by IRB banks that are already subject to the new approach. The panel presents loan characteristics at the start of our data period, or prior to the credit risk shock (this pre-event period is the average of data for 2008Q1 and 2008Q2). The variables marked change are the differences between the averages for the quarters after the event (2008Q4 to 2011Q3) and the pre-event period. There are considerable differences in the characteristics of loans provided by SA banks and loans provided by IRB banks; the differences between IRB and SA loans within IRB banks are considerably smaller. The indicator *Relationship lender* is equal to one if a bank's loans to a specific firm make up more than 75 percent of the firm's aggregate loans. *Relationship length* is the number of quarters that the relationship existed prior to our event.

IRB banks report PDs for all loans and they are on average lower for loans under IRB. Further, in line with our expectations, risk-weighted assets for IRB loans are considerably lower than risk-weighted assets for the other types of loans. The data also show a considerable rise in PDs over the shock, which—for IRB loans—is associated with a rise in risk-weighted assets by about 6.7 percent. As regulatory capital requirements are 8 percent of risk-weighted assets, this means that capital charges for loans under IRB increased by 0.54 percentage points on average (6.7 percent $\times$ 8 percent). In contrast, risk-weighted assets for SA loans are not affected by changes in PDs.

Since the German credit register does not contain information on interest rates, we follow a procedure developed by Haselmann, Schoenherr, and Vig (2013) to impute interest rates from the data that are available. Specifically, we infer the repayment structure

[12] Although Basel II was introduced in Germany in January 2007, detailed information on the regulatory approach applied to loans including the PD estimates only became available to the regulator in 2008.

of the loan contract from the quarterly data on loan amounts. We match this information with firm-level data on aggregate interest payments obtained from the Bundesbank's USTAN database. This procedure allows us to back out effective annual interest rates on individual loans. Interest rates for loans under the standard approach are on average slightly lower than interest rates for loans under IRB, while there seems to be no difference in the adjustment of interest rates over the shock. In contrast, we observe considerable differences in the adjustment of loan quantities: the average IRB loan is reduced by 7.5 percent over the shock, which is almost double the amount of the reduction for the average SA loan provided by IRB banks, and about six times the reduction of the average loan provided by SA banks.

Panel B also reports variables measured at the portfolio level, i.e., averages for variables that describe the loans in a bank's portfolio. *Portfolio share* for a loan to a firm is the ratio between the bank's loans in the two-digit SIC code industry sector and all loans in our sample within that sector. *Portfolio PD* is the average firm-specific PD for the bank's loans in that industry sector.

Finally, we match our loan data with accounting information for German firms from Bureau van Dijk's Amadeus database. The Bundesbank credit register and the Amadeus accounting information were hand-matched by company name and location. Matches were made for 7,778 firms. Firms in the matched sample are rather large, with average assets of € 153.4 million (see Panel C, Table 1). We use the matched sample in Section 5 to investigate how the aggregate of all loans to a firm change over the shock. The average total loans to the firms in our matched sample was € 22.7 million prior to the event, and declined by 7.8 percent on average following the event. Remarkably, the percentage decline in total loans to these firms is larger than the decline in the average loan within our sample. We will further examine this in Section 5.

3 Empirical Strategy

We empirically analyze how the design of capital regulation affects lending by looking first at individual loans and then at firms' overall access to funds. In this section, we describe the empirical strategies used to estimate the effects.

3.1 Loan-level lending

We develop three tests to show how banks adjust their loans in response to the credit risk shock (see Figure 3 for an illustration of our empirical strategy). We start by examining how banks that have adopted IRB (IRB banks) adjust their loans relative to banks still using the standard approach (SA banks) around the shock. We refer to this as Test 1 and estimate the following specification:

$$\Delta \mathit{Log(loans)}_{ij} = \alpha_i + \beta \; \mathit{Share\ IRB}_j + X'_{ij}\gamma + \epsilon_{ij}. \tag{1}$$

The dependent variable is the change in the logarithm of loans from bank j to firm i around the credit risk shock. We collapse the quarterly data into pre- and post-event averages (as defined in Section 2.3) in order to avoid problems of serial correlation (Bertrand, Duflo, and Mullainathan 2004).[13] Thus, there is one observation per firm-bank relationship. *Share* IRB_j is the percentage share of all loans of the bank that are subject to the IRB approach. Control variables are denoted by X_{ij}. Standard errors are double-clustered at the bank and firm level in all our regressions.

Following Khwaja and Mian (2008), we capture differences in firm demand by including firm fixed effects, α_i. Thus, our coefficient β indicates whether the same firm, borrowing from (at least) two different banks, experiences a larger decline in lending from banks that use IRB for a larger share of their loans. If, however, the credit risk shock (or other confounding events) affected banks that differ in their share of IRB loans in a systematically different way, and the variables X_{ij} are unable to control for these differences, the correlation between *Share* IRB_j and the error term, ϵ_{ij}, might be non-zero. In this case, β would be biased.

To address this concern, we develop tests that exploit the gradual introduction of model-based regulation in Germany. Importantly, at the time of the credit risk shock, banks that had introduced IRB had shifted only some of their loan portfolios to the new approach. Thus, there is variation in the regulatory approach within the same bank, which allows us to refine the identification strategy. To start, we test whether the results from Test 1 are due to bank heterogeneity. That is, we examine whether—for the same firm—SA loans from banks that have begun to introduce IRB and loans from SA institutions are affected differently by the shock (Test 2 in Figure 3). Neither the SA institution's capital charges nor those for an IRB bank's SA loans are affected by an increase in the credit risk of the borrowing firm. If differences in lending behavior are due to the regulatory approach rather than bank differences, then Test 2 should not show any effects.[14]

Our strongest identification strategy compares IRB and SA loans to the same firm from different banks that have introduced the IRB approach for some of their loan portfolios (Test 3 in Figure 3). To identify the effect of differences in capital regulation on loan amounts within IRB institutions, we restrict the sample to firms that borrow from at least two IRB banks—one bank where the loan is in the IRB pool and another where the loan is still subject to SA—and estimate the following equation:

$$\Delta \mathit{Log(loans)}_{ij} = \alpha_i + \alpha_j + \delta \; \mathit{IRB\ loan}_{pj} + X_{ij}'\gamma + \epsilon_{ij}, \qquad (2)$$

where p denotes the loan pool and $\mathit{IRB\ loan}_{pj}$ takes the value of one if the respective loan is in the IRB pool and zero if the loan is in the SA pool of bank j. Test 3 shows whether the same firm—borrowing from two different IRB banks—experiences a larger decline in its loans under IRB as compared with its loans under SA. In contrast to Equation (1), this specification allows us to include bank fixed effects, α_j, that systematically control for heterogeneity across banks (compare with Jiménez et al. 2014). This is valuable because other confounding events might affect banks differently.

Identification in Test 3 rests on the assumption that there is no systematic relationship between the initial assignment of loans to the IRB pool and the bank's adjustment of loans in response to the shock. Since we are able to systematically control for firm as well as bank heterogeneity in Equation (2), the only concern would be relationship specific factors

[13] We could also estimate Equation (1) without time averaging the data if we replace the firm fixed effects with firms × quarter interactions. Results with this specification are qualitatively very similar.

[14] If our findings in Test 1 are driven by bank heterogeneity, we would expect similar effects with this sample of SA loans.

correlated with the time at which a specific loan is shifted to IRB. As explained in Section 2 only entire loan portfolios—and not individual loans—can be shifted to IRB. Therefore, whether a specific loan was switched to IRB depends on portfolio characteristics rather than characteristics of the loan or the firm's banking relationship.

To examine this selection issue empirically, we regress $IRB\ loan_{pj}$ which indicates whether a loan was shifted to IRB prior to the credit risk shock on loan relationship and portfolio characteristics. There are two portfolio characteristics that may impact the IRB selection: (1) since the regulator only approved risk models of portfolios that had sufficient data for calibration, the size of a loan portfolio, *Portfolio share*, should be positively correlated with $IRB\ loan_{pj}$; (2) banks have an incentive to first shift those loan portfolios that carry the smallest risk (measured by *Portfolio PD*), since for these portfolios the shift to IRB would provide the greatest reduction in capital charges. Results in Table 2 show that only the size of the portfolio is related to the selection of loans, while all loan relationship characteristics such as the size of the loan, the collateral ratio, the indicator for relationship lending and the relationship length do not have a significant impact. This result holds in the sample of all loans from IRB banks (columns 1-3) and in the sample of loans to firms with at least one IRB loan and at least one SA loan from an IRB bank that we use for identification in Test 3 (columns 4-6). Consequently, we keep *Portfolio share* as a control for selection in our tests.

To address remaining concerns regarding the selection of IRB loans, we exploit a feature in the risk weight formula relating PDs to risk-weighted assets that was introduced to promote lending to small and medium enterprises (SMEs). As illustrated in Figure 4, risk weights vary with firm sales when sales are less than € 50 million, which means that an identical increase in the PD induces a smaller increase in the risk weight for loans to SMEs. Consequently, capital charges for IRB loans to these firms are less affected by the credit risk shock. By testing whether the effect estimated in Equation (2) is less pronounced for SMEs we can provide evidence on the pro-cyclicality of model-based regulation that is independent of the initial assignment of loans to the IRB group. Specifically, we can include bank × IRB fixed effects (i.e., fixed effects for the SA and IRB pool of each bank) and estimate the following equation:

$$\Delta Log(loans)_{ij} = \alpha_i + \alpha_{pj} + \zeta \left[IRB\ loan_{pj} \times Log(firm\ sales)_i \right] + \epsilon_{ij}, \qquad (3)$$

where the variable $Log(firm\ sales)_i$ is equal to the logarithm of sales for firms with a turnover lower than the threshold, and equal to the logarithm of 50 million for larger firms. Bank × IRB fixed effects are denoted by α_{pj} and account for any potential difference between the IRB and SA pool of bank j. The coefficient of interest, ζ, indicates whether the relative adjustment of IRB loans is less severe for loans to SMEs that benefit from the discount in capital charges.[15]

[15] In similar specifications, we investigate whether the IRB effect is more pronounced for loans to which the bank has a large exposure, or for loans to less profitable firms for which the PD is more likely to increase. These tests also include bank × IRB fixed effects that address concerns regarding the selection of IRB loans.

3.2 Firm-level borrowing

In the previous section we developed tests to identify the effect of the credit risk shock on the adjustment of individual loans. Here we explore the effect of IRB regulation on the ability of firms to access funds. Firms may be able to offset the pro-cyclical effects on loans subject to IRB by obtaining funds from other banks. We examine whether the change in firms' total outstanding loans around the credit risk shock depends on $\overline{\mathit{IRB\ loan}_i}$, the share of the firms' loans that were under IRB prior to the event:

$$\Delta \mathit{Log(firm\ loans)}_i = \alpha + \beta\ \overline{\mathit{IRB\ loan}_i} + X_i'\gamma + \epsilon_i. \tag{4}$$

The dependent variable is the change in the logarithm of a firm's total loans over the credit risk shock. The vector X_i' includes firm controls and weighted averages of bank control variables.[16] Standard errors in the firm-level regressions are clustered by the firms' largest lender.

Firms that borrow mostly from SA banks may differ from firms that borrow mostly from IRB banks, most notably in their demand for loans. E.g., small firms are more likely to borrow from smaller banks which are largely SA institutions. As we cannot directly control for loan demand in the firm-level regression, we estimate Equation (4) on a restricted sample of firms that have both SA loans and IRB loans from IRB banks. In this case the explanatory variable is $\overline{\mathit{IRB\ loan}_i}^*$, which is the share of a firm's loans from IRB banks that are subject to the IRB approach. That is, we focus on firms that borrow mostly from IRB banks and check whether—among those firms that have multiple loans from IRB banks—firms with a larger share of IRB loans experience a greater reduction in aggregate loans over the shock.[17]

Additionally, we also report β coefficients from Equation (4) with an adjustment for potential credit demand shocks on the firm level as suggested by Jiménez, Mian, Peydró, and Saurina (2011). The adjustment uses the difference between firm fixed effect and OLS estimates on the loan level to proxy for the unobserved covariance between credit supply and demand shocks on the firm level. Specifically, the adjusted coefficient is defined as follows:

$$\widehat{\widehat{\beta}} = \widehat{\widehat{\beta}}_{OLS} - (\widehat{\beta}_{OLS} - \widehat{\beta}_{FE}) \times \frac{\sigma_L^2}{\sigma_F^2}, \tag{5}$$

where $\widehat{\widehat{\beta}}_{OLS}$ and σ_F^2 are the firm-level OLS coefficient and the variance of $\overline{\mathit{IRB\ loan}_i}^*$, while $\widehat{\beta}_{OLS}$, $\widehat{\beta}_{FE}$ and σ_L^2 are loan-level OLS and fixed effect coefficients and the variance of $\mathit{IRB\ loan}_{pj}$.

[16] We use the amount that the firm borrows from a certain bank divided by the firms' total loans prior to the shock as a weight.

[17] Aggregate loans to these firms also include loans from SA banks that are not taken into account for the definition of $\overline{\mathit{IRB\ loan}_i}^*$. However, loans from IRB banks account for 85.4 percent of total loans for the average firm in this sample. The remaining loans from SA banks simply add noise and thus prevent us from finding a significant impact of the share of a firm's loans from IRB banks that are subject to IRB on changes in total firm loans.

4 Regulatory capital and changes in bank lending

This section presents results for the specification on the loan level described in Section 3.1. Further, we provide additional cross-sectional results that support our argument.

4.1 Main results

We start by testing whether banks that adopted the IRB approach (IRB banks) adjusted their loans differently in response to the credit risk shock than banks that continued to use the SA (Test 1). Estimates for Equation (1) are reported in Table 3, columns 1 to 3. Since observations of firms with a single lending relationship get absorbed by firm fixed effects, we restrict the sample to firms that have at least two loans—one loan from an SA bank and one loan from an IRB bank, or two loans from distinct IRB banks.[18] Column 1 indicates that the larger the share of IRB loans within a bank, the more the bank reduces its loans to a given firm. Firm-specific credit demand shocks are absorbed by the firm fixed effects. Adding control variables (bank size, capitalization and profitability, bank type indicators and *Portfolio share*) in column 2 reduces the magnitude, but not the significance of the coefficient. In column 3, we replace *Share IRB* with *IRB bank*, a dummy indicating whether the lender is an IRB institution, and still find a significant effect.

To illustrate the economic impact of the effect, we compare the change in loans by an SA bank to the change in loans by the average IRB bank. For an SA bank *Share IRB* is zero and the average value for an IRB bank is 0.62. Thus, the average IRB bank reduced its loans to the same firm by 5.0 percent more than a bank still using SA (column 1). The difference in the change in loans is 3.3 percent when bank controls are included, column 2. The coefficient on the dummy or indicator variable shown in column 3 implies that IRB banks reduced their loans by about 3.1 percent more than SA banks on average.[19]

Next, in columns 4-6 of Table 3, we present results for Test 2, where our sample is restricted to SA loans made by both SA and IRB institutions.[20] We test whether IRB banks change SA loans to the same firm more than SA banks. Although, the coefficient on *Share IRB* is significant in column 4, implying that IRB institutions reduced their loans over the shock more than SA institutions, the effect disappears when we control for bank characteristics in column 5 and in column 6. Moreover, the coefficients are smaller than the corresponding coefficients for Test 1 in all cases. As before, firm fixed effects absorb any firm-specific credit demand shocks and ensure that we are comparing relative changes in loans to a given firm. The results so far support our claim that the regulatory approach itself induced a stronger reduction of loans from IRB banks or banks with more IRB loans.

We now turn to our strongest identification test for which the sample is restricted to loans made by IRB banks.[21] Estimates of Equation (2) are reported in columns 7

[18] There are 20,740 firms with loans that meet these criteria. Overall, these firms have 93,370 loans; 44,423 are SA loans and 48,947 are IRB loans.

[19] The effect is equal to $exp(\beta) - 1$, where β is the dummy coefficient (Halvorsen and Palmquist 1980).

[20] There are 10,496 firms that have at least one SA loan from an SA bank and at least one SA loan from an IRB bank or two SA loans from different IRB banks. These firms have a total of 49,492 SA loans; 35,852 are from SA banks and 13,640 are from IRB banks.

[21] There are 7,159 firms with at least one IRB and one SA loan from two different IRB institutions.

to 9 of Table 3. The key results are the significant negative coefficients on the *IRB loan* dummy which indicates whether the loan was transferred to IRB prior to the credit risk shock. The results in column 7 indicate that within the same firm, loans subject to IRB are reduced by about 3.8 percent more than loans subject to SA. The effect is robust to the inclusion of bank-level control variables in column 8. Since IRB banks have SA and IRB loans, we can systematically account for bank heterogeneity by including bank fixed effects (column 9). We still find a significant effect of the regulatory approach on changes in loans to the same firm. This provides evidence that the regulatory approach used for a specific loan has a strong and economically meaningful influence on the extent to which the loan was 'crunched' in response to the credit risk shock. Increases in risk weights during economic downturns force capital-constrained banks that use the internal ratings-based approach to deleverage in order to fulfill their capital requirements. Results for Test 3 indicate that they do so by reducing the very assets that caused the increase in capital requirements: loans that are subject to IRB. Loans that are subject to the standard approach, on the other hand, are relatively less affected.[22]

To account for potential selection concerns resulting from the order in which loan portfolios were shifted to IRB, our estimates include the relative size of a loan portfolio (i.e., *Portfolio share*, the share of bank j's loans in firm i's two-digit SIC industry sector) as a control variable. The coefficient on *Portfolio share* is positive and—in most regressions—insignificant. Hence, if anything, banks tend to adjust loans less in response to the shock in portfolios where they are relatively active. Thus, the selection of IRB loans would bias our estimates against finding a significant effect of the choice of the regulatory approach on changes in loans over the event. Further evidence that mitigates concerns regarding selection is presented in Section 4.2.

So far, we have focused on changes in the size or volume of lending relationships which we call the intensive margin. We can also ask whether IRB banks are more likely to end an existing relationship entirely if the loan is subject to IRB as compared with SA, the extensive margin. These tests are found in Table 4 where the dependent variable is a dummy variable, *Exit*, that equals one for loans that existed in the second quarter of 2008 but that ceased to exist at some point following the event. The equations follow the specifications for Test 3 in Equation (2). The coefficient for *IRB loan* is positive, but insignificant in most cases, indicating that the effect of the regulatory approach is less pronounced on the extensive as compared with the intensive margin of lending.[23]

In addition to the volume of lending, the approach used to determine capital charges might also affect the price of lending, the interest rate charged on a loan. Since an increase in firm PDs results in higher capital charges on IRB loans, banks might react by increasing the interest rate charged on these loans. We explore this possibility by estimating Equation (2) for Test 3 with the change in interest rate instead of the change

These firms have a total of 27,620 loans: 9,226 SA loans and 18,394 IRB loans.

[22] The magnitude of these effects is in line with evidence on aggregate lending provided by Aiyar et al. (2014). They find that an increase in capital requirements by 1 percentage point induces a fall in bank-level loan growth by 6.5 to 7.2 percentage points. Studies estimating the effect of higher bank capital ratios on loan growth usually find somewhat smaller effects (see Carlson, Shan, and Warusawitharana 2013 for an overview).

[23] This is consistent with a finding by Jiménez et al. (2013), who argue that the more moderate effect on the extensive margin is due to a time lag, since lending relationships end only when all loans—including those with a longer maturity—are fully repaid.

in loans as the dependent variable. Results are summarized in Table 5. The coefficient on the *IRB loan* dummy is positive, indicating that interest rates increase relatively more on IRB loans, but the effect is small and statistically insignificant (column 1). This result holds if we add bank specific control variables (column 2), bank fixed effects (column 3), and firm fixed effects (column 4). These findings suggest that banks react to the increase in capital charges on IRB loans by reducing loan quantities instead of increasing interest rates.

4.2 Risk weights and lending to small and medium enterprises

In this section, we exploit an institutional feature of the Basel regulation—the capital charge discount for loans to SMEs—to address remaining concerns regarding the selection of IRB loans at the outset of our sample period. The idea behind the test is quite simple: the slope of the mapping from PDs into risk weights is smaller for loans to SMEs as compared with loans to larger firms at any point of the mapping (see Figure 4). Consequently, capital charges for IRB loans to SMEs are less affected by the credit risk shock. We now examine whether the relative reduction of IRB loans compared with SA loans to the same firm is less pronounced for SMEs. In this way, we can provide evidence on the pro-cyclicality of model-based capital regulation while systematically controlling for the initial assignment of loans to the IRB group.

As a starting point, we restrict ourselves to loans subject to the IRB approach for which we have information on the firm's sales, and check whether the lending adjustment in response to the credit risk shock is related to the sales of the firm (Table 6). IRB loans to firms with lower sales are reduced less over the credit risk shock (column 1), while there is no relationship between firm sales and adjustments in lending for loans under SA (column 2). Further, we find a significantly negative coefficient on the interaction between *Log(firm sales)* and the *IRB loan* dummy (column 3) that is robust to the inclusion of firm fixed effects (column 4) and bank × IRB fixed effects (column 5). This means that IRB banks reduce IRB loans to the same firm relatively more than SA loans, but less so if the loan benefits from the capital charge discount for SMEs. Specifically, we can compare a firm with sales of € 25 million to a large firm with sales over € 50 million. The IRB effect is 1.3 to 3.2 percentage points larger in magnitude for loans to the larger firm which does not benefit from the capital charge discount (columns 3-5, bottom row). Importantly, these effects are not driven by the selection of IRB loans, as bank × IRB fixed effects in column 5 systematically control for any potential difference between the SA and IRB pool of a specific bank. Changes in capital charges seem to exert a strong influence on the lending adjustment over the credit risk shock.

4.3 Impact of bank, loan, and firm characteristics

In this section, we present further cross-sectional results. Specifically, we expect a stronger reduction in outstanding loans in response to the credit risk shock (a) for loans by banks with a low capital ratio prior to the recession; (b) for large IRB loans that have a substantial impact on bank capital charges when their PD deteriorates; and (c) for loans to firms for which PDs are more likely to increase in the recession.

Hellwig (2010) argues that banks reduced buffers over minimum capital requirements to a bare minimum in an attempt to 'economize on equity' prior to the crisis, and that there was only limited scope for raising additional equity during the crisis. Consequently, we expect that banks with initially lower capital ratios which are closer to the regulatory minimum will have a stronger reaction when capital requirements increase due to the credit risk shock. We test this by introducing an interaction between *IRB loan* and the bank's initial equity ratio in column 1 and an interaction with a dummy variable for banks with a higher than median pre-event equity ratio, *High equity*, in column 2 of Table 7.[24] The significantly positive coefficient for the interaction in column 1 shows that the IRB effect is mitigated as the bank's pre-event equity ratio increases. Similarly, the positive interaction coefficient in column 2 indicates that the effect of the regulatory approach is more pronounced for IRB loans from banks that had lower capital ratios prior to the event. As shown at the bottom of the table, the magnitudes are large. For example, moving from the 25^{th} to the 75^{th} percentile of *Bank equity ratio*, the stronger reduction of IRB loans is reduced by 3.1 percentage points (column 1).

Next, we investigate whether the size of a loan has an influence on how it is affected by the credit risk shock. Our concern is that increases in risk weights for larger loans result in larger increases in required capital and hence banks may respond more. To test this, we calculate the bank's exposure to each loan by dividing the loan amount prior to the shock by the bank's pre-event total assets. Alternatively, we take the absolute size of the loan instead of the relative exposure of the bank as a criterion. We then generate two dummy variables; the first, *High exposure*, takes the value one if the exposure of the bank to a certain loan is larger than the median exposure in our sample, and the second, *Large loan*, takes the value one if the loan is larger than the median loan in our sample. In contrast to the bank equity measures these variables are on the loan level, which is why we can include bank $\times$ IRB fixed effects as in Section 4.2. We show the results in columns 3 and 4 of Table 7. The coefficients for the interaction terms are significantly negative, indicating that the IRB effect is particularly pronounced for large exposures, i.e., for loans for which increases in risk estimates translate into relatively large increases in capital requirements. The effects are large; for example, the coefficient in column 3 implies that the IRB effect is 14.1 percentage points larger for loans to which the bank has a larger than median exposure. This indicates the magnitude of potential real effects of model-based regulation. As the IRB effect is particularly pronounced for large loan exposures, effects on the aggregate firm level could be even larger than those on the loan level. We examine this issue in the next section.

Finally, our tests in Section 4.1 assumed that the shock uniformly increased PDs for IRB loans. However, a recession hits firms heterogeneously, and capital requirements increase the most for loans to firms whose PD increases the most. As explained before, relating the observed changes in the PD to changes in lending is problematic, as the risk assessment and the lending decision of a bank are endogenous. Therefore we use a firm's pre-shock profitability, measured by its ROA in 2007-08, since it is not directly affected by the banks' lending decision, but is likely to be observed and employed by the bank's analysts in order to predict future changes in the PD. Data on firm ROA is available for

[24] In principle, it would be possible to include firm fixed effects in this equation to control for firm-specific credit demand shocks as before. However, such a specification requires that each firm has at least four banking relationships in order to identify the coefficients.

3,370 firms that have both SA and IRB loans. We interact the *IRB loan* dummy with the *Firm ROA* or a dummy for firms with above median ROA, *High ROA*, and present regression results in column 5 and 6 of Table 7.[25] As expected, the interaction terms are positive in both instances, although only the coefficient in column 5 is statistically significant. These findings are consistent with our main argument: IRB loans are reduced more than SA loans to the same firm, especially if the firm has a lower ROA prior to the event and is hence more likely to experience an increase in the PD that would affect capital charges.

5 Capital regulation and firms' overall access to funds

In this section we turn our attention to firms' overall access to funds. Specifically, we examine whether the pro-cyclical effects on loan balances documented above persist at the firm level. That is, are firms able to offset a reduction in loans from one bank by increasing their borrowing from another bank? Did firms relying on IRB loans experience a stronger reduction in aggregate loan supply? These questions are central for evaluating the real sector effects of capital charges based on credit-specific risks.

Firm-level results are shown in Table 8, where the event is defined as before and the dependent variable is the change in the logarithm of total loans to the firm. We start by estimating Equation (4) to determine the effect of the share of a firm's loans that are subject to IRB on the change in the firm's total outstanding loans using all 107,025 firms in our data (column 1 of Table 8).[26] Firms with a larger share of loans subject to IRB prior to the event experienced larger reductions in total borrowing. The coefficient remains highly significant and even increases in magnitude if we include variables that control for the average characteristics of a firm's lenders in column 2, and firm-level control variables in the matched sample of 7,778 firms in columns 3 and 4. The coefficient on $\overline{IRB\ loan_i}$ in column 2 implies that a firm that had only IRB loans experienced a reduction in total loans that is 5.6 percent larger than the decline in loans for a firm that had only SA loans. This effect increases to 11.3 percent in the matched sample where we control for firm level characteristics (column 4). Interestingly, these aggregate firm effects are large compared to those previously shown at the loan level. After a credit risk shock, firms seem to be unable to compensate for the reduction in IRB loans by switching to SA loans. Furthermore, the stronger reduction of IRB loans documented at the loan level is particularly pronounced for large loan exposures (see Section 4.3). It is likely that the combination of these two effects is responsible for the sizable effect of model-based capital regulation on firms' overall access to funds.

To address potential differences in loan demand by firms that borrow from SA and IRB institutions, we restrict the sample to firms that have both SA and IRB loans from IRB banks, i.e., to the 7,159 firms we use for identification in Test 3. Although the sample is much smaller, there continues to be a significant impact of the share of a firm's loans from IRB banks that are subject to IRB ($\overline{IRB\ loan_i}^*$) on changes in firms' aggregate

[25] As ROA varies on the firm level, we can include firm fixed effects in addition to bank × IRB fixed effects. The sample includes loans from SA banks; the sample size would otherwise be very small for Test 3 which would include SA and IRB loans from IRB banks.

[26] This sample includes single-relationship firms as well as firms that have only SA loans or only IRB loans. For these firms, $\overline{IRB\ loan_i}$ is equal to 0 or 1, respectively.

borrowing (Table 8, column 5). Again, the result is robust to the inclusion of weighted bank-level characteristics as well as firm-level characteristics (columns 6 to 8). The effect is economically meaningful: the firm at the 75^{th} percentile of $\overline{IRB\ loan_i}^*$ (which had 81.7 percent IRB loans) experienced a 3.0 to 4.6 percent larger reduction in aggregate loans than the firm at the 25^{th} percentile (which had 42.6 percent IRB loans).

Finally, we apply the Jiménez et al. (2011) procedure described in Section 3.2 to adjust the IRB effects for firm demand. The adjusted coefficients are shown at the bottom of the table. The corrections are relatively small in columns 1-4; in columns 5-8 they reduce the effects by about one third. The corrections indicate that it is unlikely that our findings are driven by heterogeneity in firms' demand for credit. Overall, the results in Table 8 provide strong evidence for a significant effect of the regulatory classification of loans within IRB banks on aggregate firm borrowing following the credit risk shock.

We also examine whether a firm's share of IRB loans affected its aggregate borrowing costs. We use the ratio of aggregate interest expenses to total borrowing from the balance sheet and income statement to measure average borrowing costs for the firm. Regression results are summarized in Table 9. Column 1 indicates that firms obtaining a larger share of IRB loans experience a greater increase in capital cost over the shock. However, this result vanishes once we include the average bank-level controls in column 2. In columns 3 and 4 we reduce the sample to firms that have both SA and IRB loans from IRB banks in order to account for potential differences in firm demand as before. The coefficient for the IRB variable in the reduced sample, $\overline{IRB\ loan_i}^*$, is insignificant in both regressions. There is little evidence that firms that have more loans subject to the IRB regulatory approach experience significantly greater increases in capital costs over the credit risk shock. These results suggest—along with the loan-level results in Section 4.1—that banks reacted to the credit risk shock by adjusting the amounts of IRB loans outstanding in order to deleverage and fulfill regulatory requirements rather than increasing the cost of loans.

6 Robustness and further results

In this section we relax some of the assumptions regarding our data and sample period to see if our results are robust. We find that our results on both the loan and firm level are not materially affected.

6.1 Ordinary least square results

Our results in Section 4.1 only include firms with multiple lending relationships, as this is a necessary condition for the inclusion of firm fixed effects. Here we include firms with a single bank relationship and estimate the regressions with OLS. Results are presented in Table A.2 in the Appendix and are qualitatively similar to the fixed effect results. Coefficients decrease in magnitude when we include single-relationship firms, which suggests that the IRB effect is less pronounced for these firms.

6.2 Confounding shocks and selection issues

The focus of our analysis is the differential adjustment of loans under different regulatory approaches in response to the credit risk shock. This shock was preceded by two related events: the introduction of the Basel II approach at the beginning of 2007, a policy shock, and the banking crisis associated with problems in several 'Landesbanks' and commercial banks. Our concern here is to show that our results reflect responses to the credit risk shock rather than delayed responses to earlier events. To begin, note that the policy shock and the credit risk shock work in opposite directions. Basel II reduced capital charges for IRB loans and should therefore, ceteris paribus, increase lending on these loans. The credit risk shock increased PDs and risk weights which increases capital charges and should reduce lending. As a consequence, any lingering effect of the policy shock in our event study should work against our findings.

To further explore the influence of prior events we conduct placebo tests to examine whether there are differences in the adjustment of different types of loans prior to the credit risk shock. Specifically, we estimate difference-in-difference specifications similar to our Test 3, but using alternative time horizons. For example, we check whether loans under IRB and SA were adjusted differently between 2007 and 2008, between 2006 and 2007, and so on.[27] Columns 1-4 of Table 10 reveal no significant differences in the adjustment of the different types of loans prior to the credit risk shock in 2008Q3. If anything, prior to the Lehman collapse, loans using IRB were increased relative to loans using SA, as indicated by the positive (but insignificant) coefficient in column 1. Overall, these placebo tests make us confident that pre-trends, i.e. the delayed effects of the policy shock in 2007 or other events, are unlikely to be affecting our results.

We noted that several German banks had problems already in 2007 and might have reacted by adjusting their loans prior to our event. Our main identification test includes bank fixed effects and thus accounts for bank heterogeneity around the event in a systematic manner. However, to avoid any confusion between the banking crisis and the real sector event, we can start the pre-shock period in late 2006 instead of early 2008. In column 5 of Table 10 we show results for Test 3 where the dependent variable is the difference in the logarithm of loans between late 2006 and our usual post-event period. Although there are substantially fewer loans in this data set, the core result is maintained: loans that were moved to IRB before the shock decline relatively more. Alternatively, we can remove from the sample the financial institutions that faced difficulty prior to the Lehman shock. These are the 'Landesbanks' identified by Puri et al. (2011): WestLB, BayernLB, and SachsenLB and the commercial banks, IKB and Hypo Real Estate. The coefficient on the IRB dummy remains significantly negative (column 6) when loans from these institutions are excluded.

Our testing framework acknowledges that each bank-firm relationship was subject to either SA or IRB regulation at the time of the credit risk shock and does not exploit the variation over time in regulatory treatment. Due to the gradual phase-in of Basel II, loans were moved from SA to IRB throughout our sample period which means that the policy shock continues to affect certain loans as our event occurs. To avoid any confusion, we re-estimated Test 3 on the sample of loans that are consistently classified as either SA or IRB throughout the period. The result with this smaller sample in column 7 of Table 10 confirms that IRB loans are reduced significantly more than SA loans to the same firm.

[27] As always, loans are classified as SA or IRB according to the regulatory approach used at the beginning of 2008, the first quarter for which such information is available. As we can only include loans that existed at the beginning of 2008, the sample becomes smaller the further we go back in time.

6.3 Examining loans that were moved from SA to IRB

We develop an additional test that exploits the timing of the change in regulatory treatment of individual loans. Our data set allows us to identify the point in time when a specific PD increased. Thus, we can test whether a loan is adjusted following a change in PD and whether the adjustment depends on the regulatory approach used for the loan. As noted before, banks' assessment of PDs and their lending reaction might be endogenous, which is why we prefer to collapse our data around the credit risk shock in our main specifications. Nevertheless, we believe that the additional tests presented here can add further insights.

Results in Table 11 show how loans are adjusted in response to a change in PD, depending on the regulatory approach used for the loan. The sample includes only loans that were subject to SA at the beginning of 2008 and shifted to IRB throughout our sample period, and only loan-quarter observations for which we observe an increase in PD. The dependent variable is the difference between the logarithm of loans two quarters following the rise in PD and the logarithm of loans in the quarter of the rise in PD. Column 1 shows that loans are reduced significantly more following a rise in PD if they have already been moved to IRB. While the average SA loan is reduced by 2.3 percent following a rise in PD, the average IRB loan is reduced by 3.9 percent. This result is robust to the inclusion of period fixed effects that control for the time at which the rise in PD occurred (column 2). Next, we further constrain the sample and include only loans for which we observe at least two increases in PD: one when the loan was still subject to SA and another one when the loan had already been moved to IRB. In this case we can include bank $\times$ firm fixed effects and examine whether—for the same bank-firm relationship—the adjustment in lending is greater when the loan has already been shifted to IRB. We find that this is indeed the case: following an increase in PD, loan amounts for the same bank-firm relationship are reduced by about 3 percent more if the relationship has already been switched to IRB (column 3). This result is robust to the inclusion of bank $\times$ period fixed effects that account for time-varying shocks at the bank level.

6.4 Addressing the € 1.5 million reporting threshold

The German credit register contains a € 1.5 million reporting threshold that could potentially bias our estimates at the firm level. In particular, it could be that we find a stronger effect at the firm level because we are missing out on smaller loans that are likely to be SA loans. In this section, we report tests that suggest that the threshold is not a serious concern.

First, we use the matched sample with data from the firm balance sheet to measure the change in aggregate firm borrowing. That is, the change in loans from the balance sheet is the dependent variable in the firm-level regression instead of the change in loans from the credit register. Thus, we ensure that we do not miss out on any loans for the firms in the matched sample. The coefficient for the IRB variable in column 1 of Table 12 is significantly negative and is similar in magnitude to the coefficient in the main test.

Second, we use the matched sample to calculate a coverage ratio defined as the ratio between aggregate loans in the credit register and total loans on the firm's balance sheet. For firms in the matched sample, the mean coverage ratio is 73 percent, and the median is 74 percent. In column 2 of Table 12 we restrict the sample to firms for which the coverage ratio is above the median. Any bias should be less severe for these firms as most of their loans are in the credit register. The coefficient on $\overline{IRB\ loan_i}$ is even larger in magnitude for the restricted sample as compared with the full sample. Next, we include only firms that are larger than the median firm in our sample (in terms of total assets), as larger firms tend to have larger loans that are more likely to be recorded in the credit register. Again, the coefficient on this restricted sample is larger than the coefficient for the full sample (column 3).

Lastly, we use a procedure suggested by Ongena, Tümer-Alkan, and Westernhagen (2012) to account for the fact that $\overline{IRB\ loan_i}$ accounts only for those loans of a firm that are recorded in the credit register. Specifically, for each firm, we estimate the amount of loans that are not recorded in the credit register by the difference between total balance sheet loans and total loans in the credit register. For this remainder, we use two extreme assumptions to calculate new versions of the IRB variable. For the first version, we assume that all of the unobserved loans are subject to SA. For the second version, we assume that all of the unobserved loans are subject to IRB. Re-estimating the firm-level regressions using the alternative IRB variables gives us an idea about the maximum size of any potential bias arising from a misclassification of $\overline{IRB\ loan_i}$. Results are presented in columns 4-5 of Table 12. The coefficient for the IRB variable remains significantly negative in both cases, and in the more likely case where unobserved loans are classified as SA loans, coefficients in the firm-level regressions become even larger in magnitude. Overall, this evidence leads us to conclude that it is unlikely that the reporting threshold in the credit register induces a bias that makes our findings stronger.

7 Conclusion and discussion

In this paper we develop identification strategies that enable us to estimate how capital regulation based on individual asset risk affects bank lending. We exploit the gradual introduction of Basel II in Germany and use the shock that accompanied the collapse of Lehman Brothers in September 2008 as an event that increased credit risk in the German market for corporate loans. Our main finding is that the counter-cyclicality of capital charges based on individual asset risk has a significant pro-cyclical effect on the lending behavior of banks as well as a considerable effect on firms' aggregate ability to borrow. For a given firm, loans by different IRB banks are reduced by 2.1 to 3.9 percent more when internal ratings (IRB) instead of fixed risk weights (SA) are used to determine capital charges. The effect is even stronger on the aggregate firm level: firms that had only IRB loans prior to the event experienced a reduction in total loans that was about 5 to 10 percent larger than the reduction for firms that had only SA loans. Thus, microprudential model-based capital regulation has sizeable macroeconomic consequences.

Our findings have important policy implications for the design of bank capital regulation. The new Basel III framework includes measures that are meant to address the problem of pro-cyclicality. Most importantly, Basel III introduces a counter-cyclical capital buffer that requires banks to build up additional capital reserves in times of excessive credit growth which can be used to satisfy capital requirements when economic conditions deteriorate. Our findings could be interpreted as justification for such a measure. However, counter-cyclical capital buffers reduce pro-cyclicality only if the supervisor has sufficient foresight about future economic conditions. Unexpected shocks to credit risk (e.g., shocks that originate abroad such as the one analyzed in this paper) cannot be anticipated and, therefore, regulators cannot always pre-empt such shocks by setting buffer rates accordingly. Furthermore, Basel III introduces capital conservation buffers. These are meant to address the problem of pro-cyclicality by reducing the pressure on banks to deleverage when economic conditions deteriorate. However, they also do not solve the basic problem of pro-cyclical capital regulation, as their release has severe consequences for banks, and markets might not accept lower capital ratios when economic conditions deteriorate. One measure that would reduce the problem of pro-cyclicality is a simple leverage ratio. However, with a leverage ratio the link between capital charges and actual asset risk would vanish. Making a final judgment on the efficiency of risk-based capital requirements requires further research on the costs and benefits of this regulatory approach.

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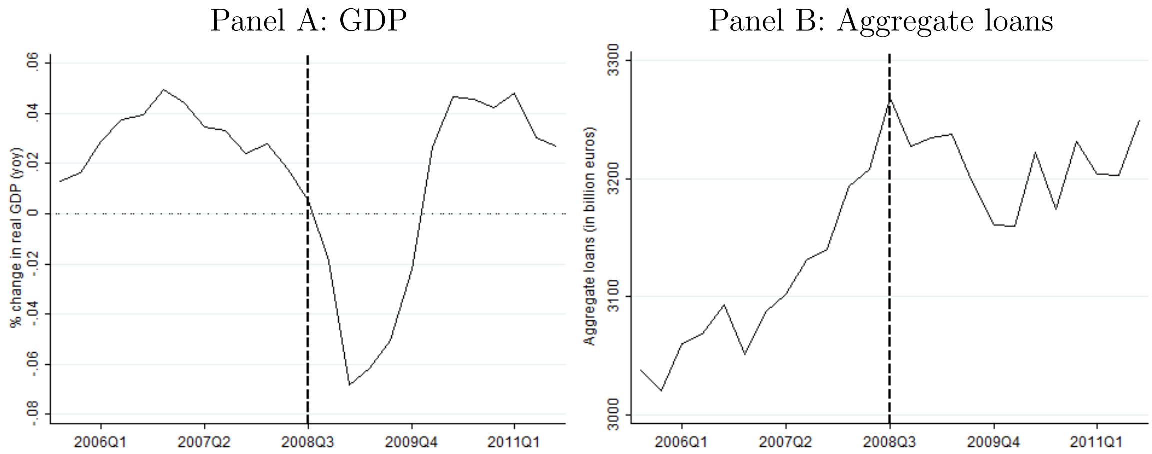

Figure 1: **The credit risk shock and the German economy.** Panel A shows the year-over-year growth rate of real GDP in Germany. Panel B shows the aggregate amount of loans (in billion euros) extended by all German banks to corporate borrowers and households. The dashed vertical line indicates the credit risk shock in September 2008. (Source: German Federal Statistical Office and Deutsche Bundesbank.)

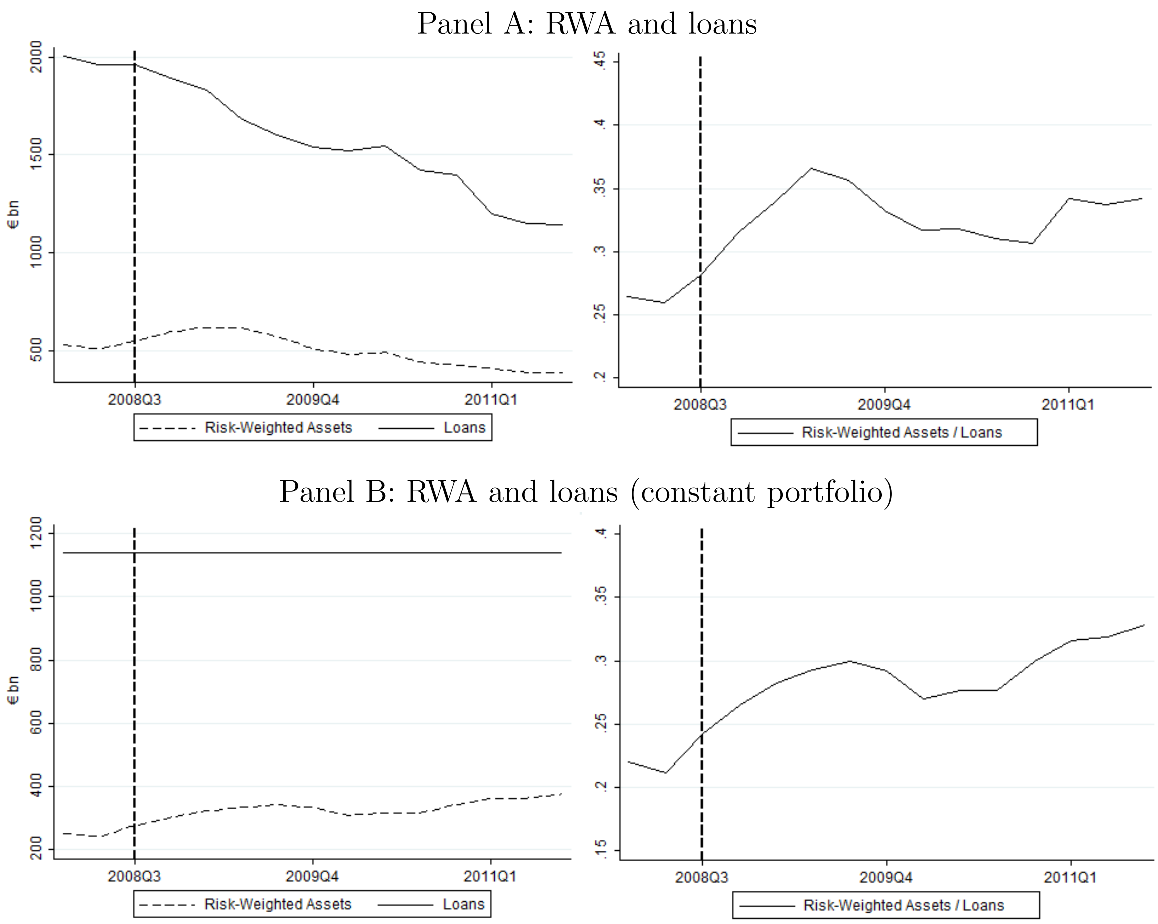

Figure 2: **Aggregate risk-weighted assets and IRB loans.** Panel A shows aggregate loans from the credit register and the corresponding risk-weighted assets. The series include only those lending relationships that existed prior to the credit risk shock; i.e., we do not include lending relationships that were originated after the event. The left graph shows loans and risk-weighted assets for these loans, and the right graph depicts the ratio of risk-weighted assets to loans. Panel B shows risk-weighted assets and loans assuming a constant portfolio of loans. We include all loans that exist throughout the entire sample period and calculate the risk weight for each loan at each point in time. We calculate hypothetical risk-weighted assets by multiplying the loan amount of 2008Q3 with the risk weight for the respective period. The aggregate of the hypothetical risk-weighted assets and the (constant) loan total are shown in the left graph. The right graph shows the ratio between the two series.

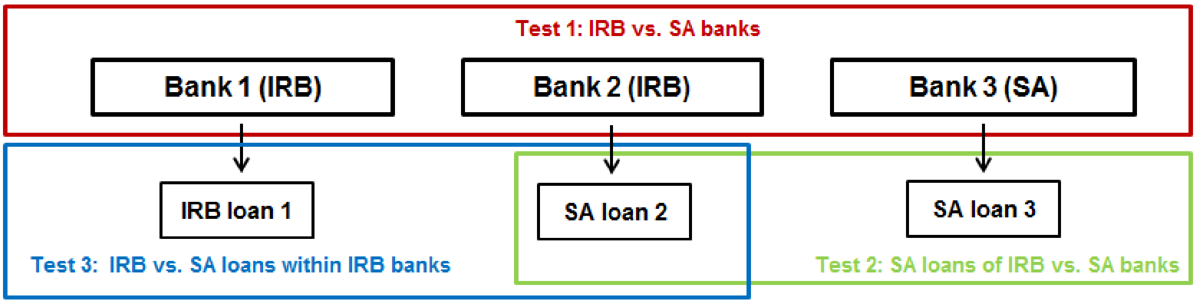

Figure 3: **Institutional setup and identification.** This figure illustrates how we use the multiple bank relationships of a typical firm for identification in the empirical analysis. Suppose a firm has three loans: one IRB loan from an IRB bank, one SA loan from an IRB bank, and one SA loan from an SA bank. In Test 1 we include all loans to firms that have at least one loan from an SA bank and one loan from an IRB bank or at least two loans from distinct IRB banks. Test 2 includes only SA loans and investigates whether there is a difference between SA loans from SA banks and SA loans from IRB banks. In Test 3 we use loans from IRB banks and test whether these banks—for the same firm—reduce their IRB loans more than their SA loans.

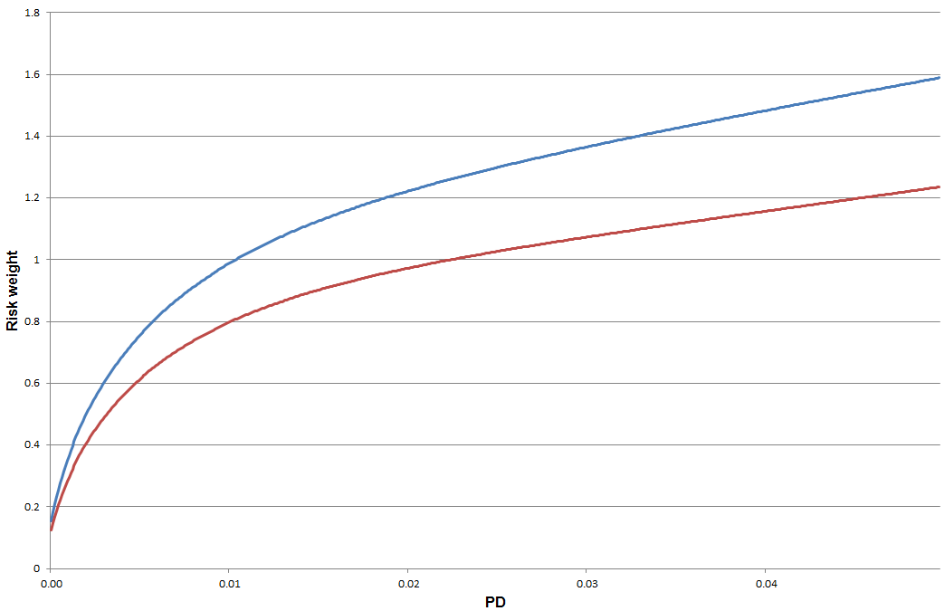

Figure 4: **PDs and risk weights.** The figure illustrates the relationship between PDs and regulatory risk weights for firms of different size. The top line shows the relationship for firms that do not benefit from any discount for SMEs, i.e., firms with a turnover larger than € 50 million. The bottom line shows the relationship for firms with a turnover of € 10 million.

Table 1:
Summary statistics

Panel A shows summary statistics for banks that introduced IRB (IRB banks) and banks that did not (SA banks). Panel B shows statistics for all loans where we were able to identify the regulatory approach. Panel C shows statistics for the matched sample of firms where we obtained balance sheet data and aggregate loans from the credit register. All level variables are measured prior to the credit risk shock, while changes indicate the difference between the average for the pre-event period (2008Q1 to 2008Q2) and the average for the post-event period (2008Q4 to 2011Q3).

Panel A: Bank-level variables

	1,784 SA banks		41 IRB banks	
	Mean	S. D.	Mean	S. D.
Share IRB - share of loans subject to IRB	0	0	0.620	0.371
Bank assets - in millions of €	1,080	2,580	138,000	307,000
Bank equity ratio - equity to assets	0.067	0.051	0.046	0.029
Bank ROA - return on assets	0.006	0.012	0.006	0.010

Panel B: Loan-level variables

	SA banks		IRB banks			
	(92,466 obs.)		SA loans (29,083 obs.)		IRB loans (61,417 obs.)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Loan size - in millions of €	8,643	22,405	19,668	43,798	25,732	50,498
Collateral ratio - collateral to *Loan size*	0.029	0.161	0.131	0.333	0.169	0.351
Relationship lender - indicator (see text)	0.470	0.499	0.545	0.498	0.468	0.499
Relationship length - in quarters	19.1	17.4	17.7	17.3	18.8	17.5
PD - probability of default	—	—	0.024	0.050	0.015	0.052
Risk weight - RWA to *Loan size*	0.662	0.373	0.612	0.432	0.435	0.449
Interest rate - imputed (see text)	0.087	0.055	0.089	0.058	0.098	0.063
Δ *Log(loans)* - change in log of *Loan size*	-0.012	0.359	-0.039	0.459	-0.075	0.569
Δ *PD* - change in *PD*	—	—	0.021	0.100	0.030	0.126
Δ *Risk weight* - change in *Risk weight*	-0.014	0.180	-0.007	0.284	0.067	0.461
Δ *Interest rate* - change in *Interest rate*	-0.017	0.036	-0.015	0.032	-0.017	0.037
Portfolio variables						
Portfolio share - see text	0.002	0.007	0.059	0.057	0.096	0.101
Portfolio PD - see text	—	—	0.022	0.018	0.017	0.016

Panel C: Firm-level variables

	Firms (7,778 obs.)	
	Mean	S. D.
Firm assets - in millions of €	153.4	347.9
Firm ROA - return on assets	0.063	0.093
Firm leverage - debt to assets	0.133	0.141
Firm sales - in millions of €	116.9	305.4
Firm loans - in millions of €	22.7	67.5
Firm capital cost - interest paid to *Firm loans*	0.0829	0.0712
Δ *Log(firm loans)* - change in log of *Firm loans*	-0.078	0.399
Δ *Capital cost* - change in *Firm capital cost*	-0.0011	0.0201

Table 2:
Determinants of loan classification

The dependent variable in all regressions is an indicator for the regulatory approach used for the loan in 2008Q1. It is equal to 1 if the loan from bank j to firm i is subject to IRB and equal to 0 if the loan is subject to the standard approach. *Log(loan size)* is equal to the logarithm of average loan size for the bank-firm relationship throughout the sample period (2008Q1 to 2011Q3). The remaining variables are defined in Table 1. The sample includes all loans from IRB banks in columns 1-3 and the loans to firms with multiple lending relationships used for identification in Test 3 in columns 4-6. Robust standard errors adjusted for clustering at the bank and and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable	*IRB loan*					
	All firms			Multiple lending relationships		
	(1)	(2)	(3)	(4)	(5)	(6)
Portfolio share	0.509*		0.492*	0.765**		0.734**
	(0.297)		(0.271)	(0.305)		(0.278)
Portfolio PD	-0.546		-0.517	-0.638		-0.596
	(1.105)		(1.126)	(0.958)		(0.975)
Log(loan size)		0.015	0.014		0.016	0.015
		(0.012)	(0.011)		(0.010)	(0.010)
Collateral ratio		0.084	0.087		0.093	0.096
		(0.094)	(0.095)		(0.077)	(0.077)
Relationship lender		-0.036	-0.038		-0.018	-0.022
		(0.037)	(0.037)		(0.050)	(0.050)
Relationship length		0.000	0.000		0.000	0.000
		(0.001)	(0.001)		(0.001)	(0.001)
Bank FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Observations	90,500	90,500	90,500	27,620	27,620	27,620
R-squared	0.849	0.850	0.851	0.553	0.558	0.560

Table 3:

Lending and the regulatory approach

The table shows the relationship between the decline in loan size and the regulatory approach used by the bank. We take the credit risk shock in late 2008 as an event and collapse all quarterly data for a given loan into a single pre- and post-event period. Data are restricted to (a) loans that are larger than € 1.5 million (b) loans from commercial, state, or cooperative banks that are subject to the Basel II capital regulation (c) loans that have an observation in both the pre- and the post-shock period. The dependent variable is the difference in *Log(loans)* between the pre- and the post-event period. In columns 1 to 3 we use observations for firms that have at least one loan from an SA bank and one loan from an IRB bank or loans from at least two distinct IRB banks (Test 1). In columns 4 to 6 the sample is restricted to SA loans and includes only firms that have at least one SA loan from an SA bank and at least one SA loan from an IRB bank or SA loans from at least two distinct IRB banks (Test 2). Finally, columns 7 to 9 include only loans from IRB banks and only firms that have at least one SA loan and at least one IRB loan from an IRB bank (Test 3). The IRB impact at the bottom of the table in columns 1-2 and 4 gives the difference in percentage points in the reduction in lending between loans from the average IRB bank (for which *Share IRB* equals 0.62) and loans from an SA bank (for which *Share IRB* equals 0); the difference between loans from IRB banks and loans from SA banks in column 3; and the difference in percentage points between loans under IRB and loans under SA in columns 7-9. Robust standard errors adjusted for clustering at the bank and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Log(loans)*								
	Test 1 IRB vs. SA banks			Test 2 SA loans of IRB vs. SA banks			Test 3 IRB vs. SA loans within IRB banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Share IRB	–0.081***	–0.053***		–0.054***	–0.043				
	(0.018)	(0.019)		(0.021)	(0.035)				
IRB bank			–0.032**			–0.030			
			(0.014)			(0.021)			
IRB loan							–0.039***	–0.040***	–0.021**
							(0.011)	(0.014)	(0.010)
Portfolio share		0.133	0.111		0.390*	0.374*		0.145	0.078
		(0.092)	(0.090)		(0.211)	(0.213)		(0.136)	(0.085)
Log bank assets		–0.011**	–0.011**		–0.007	–0.007		–0.018	
		(0.005)	(0.005)		(0.006)	(0.006)		(0.013)	
Bank equity ratio		–0.273	–0.171		–0.179	–0.157		0.540	
		(0.336)	(0.355)		(0.389)	(0.391)		(1.093)	
Bank ROA		–0.003	–0.003		0.016	0.016		–0.107**	
		(0.015)	(0.015)		(0.011)	(0.011)		(0.045)	
State bank		0.007	0.010		0.034*	0.037*		–0.018	
		(0.020)	(0.020)		(0.020)	(0.020)		(0.038)	
Cooperative bank		0.009	0.014		0.030	0.033*		–0.038*	
		(0.017)	(0.016)		(0.019)	(0.019)		(0.022)	
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Bank FE	NO	NO	NO	NO	NO	NO	NO	NO	YES
Observations	93,370	93,370	93,370	49,492	49,492	49,492	27,620	27,620	27,620
R-squared	0.270	0.270	0.270	0.250	0.251	0.251	0.297	0.299	0.307
IRB impact	–5.0 %	–3.3 %	–3.1 %	–3.3 %	—	—	–3.8 %	–3.9 %	–2.1 %

Table 4:
Extensive margin

The table examines the adjustment of lending at the extensive margin. The dependent variable *Exit* is a dummy that is equal to 1 if a loan that existed in the second quarter of 2008 ceased to exist after the credit risk shock. All columns include only loans from IRB banks, and columns 3 and 4 include only firms that have at least one SA loan and at least one IRB loan from an IRB bank. *State bank* and *Cooperative bank* are indicator variables for the bank type. Robust standard errors adjusted for clustering at the bank and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	*Exit*			
	(1)	(2)	(3)	(4)
IRB loan	0.069*	0.028	0.044	0.027
	(0.039)	(0.040)	(0.030)	(0.024)
Portfolio share	0.569***	0.432	0.163	–0.005
	(0.214)	(0.292)	(0.148)	(0.296)
Log bank assets	0.002		–0.042***	
	(0.013)		(0.011)	
Bank equity ratio	0.796		–0.018	
	(1.263)		(1.026)	
Bank ROA	–0.016		0.047	
	(0.112)		(0.068)	
State bank	–0.110***		–0.069**	
	(0.042)		(0.032)	
Cooperative bank	–0.134**		–0.097***	
	(0.057)		(0.034)	
Constant	0.397			
	(0.364)			
Firm FE	NO	NO	YES	YES
Bank FE	NO	YES	NO	YES
Observations	90,500	90,500	27,620	27,620
R-squared	0.038	0.059	0.453	0.465

Table 5:
Interest rates

The table examines how changes in interest rates over the credit risk shock depend on the regulatory approach used for a specific loan. The dependent variable is the difference in *Interest rate* for a specific loan between the pre- and the post-event period. Bank controls in column 2 are the same as in Table 3. Robust standard errors adjusted for clustering at the bank and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Interest rate*			
	(1)	(2)	(3)	(4)
IRB loan	0.0008	0.0009	0.0001	0.0008
	(0.0011)	(0.0011)	(0.0014)	(0.0019)
Bank controls	NO	YES	—	—
Bank FE	NO	NO	YES	YES
Firm FE	NO	NO	NO	YES
Observations	3,132	3,132	3,132	3,132
R-squared	0.0003	0.0113	0.0165	0.8795

Table 6:
Lending to small and medium enterprises

The table shows the relationship between the decline in loan size, the regulatory approach used by the bank, and the size of the firm. The dependent variable is the difference in *Log(loans)* between the pre- and the post-event periods. The variable *Log(firm sales)* is equal to the logarithm of total sales for firms with a turnover less than € 50 million and equal to the logarithm of 50 million for firms with a larger turnover; it accounts for the capital charge discount given to loans to SMEs. The Size impact at the bottom of the table gives the difference in percentage points in the relative reduction of IRB loans to firms with total sales of € 50 million and firms with total sales of € 25 million. Robust standard errors adjusted for clustering at the bank and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Log(loans)*				
	(1) IRB loans	(2) SA loans	(3) All loans	(4) All loans	(5) All loans
Log(firm sales)	-0.009**	-0.002	0.006		
	(0.004)	(0.009)	(0.006)		
IRB loan			0.141	0.340**	
			(0.086)	(0.136)	
IRB loan × Log(firm sales)			-0.014*	-0.035***	-0.026**
			(0.008)	(0.013)	(0.013)
Constant			-0.104		
			(0.066)		
Firm FE	NO	NO	NO	YES	YES
Bank × IRB FE	YES	YES	NO	NO	YES
Observations	10,374	4,146	14,520	14,520	14,520
R-squared	0.011	0.063	0.000	0.517	0.533
Size impact	—	—	–1.3 %	–3.2 %	–2.4 %

Table 7:
Firm, bank, and loan characteristics

These regressions examine the interaction between the IRB effect and bank, loan and firm characteristics. As before, the dependent variable is the difference in *Log(loans)* between the pre- and the post-event period. In columns 1 and 2 we interact *IRB loan* with the *Bank equity ratio* (column 1) or with *High equity*, a dummy that indicates whether the bank equity ratio is above the median (column 2). Bank control variables are the same as in previous tables. In column 3 we interact *IRB loan* with *High exposure*, a dummy that indicates whether a bank's exposure to a specific loan (defined as the loan amount divided by the bank's total assets prior to the shock) is larger than the median, and in column 4 with *Large loan*, a dummy that indicates whether a specific loan is larger than the median loan in our sample. Columns 5 and 6 use a matched sample of 14,336 loans to 3,370 firms for which we are able to obtain balance sheet information and that have at least one SA loan and one IRB loan. We interact *IRB loan* with the *Firm ROA* (column 5) or a dummy that indicates whether the firm's pre-shock ROA is higher than the median (column 6). The Differential impact at the bottom of the table gives the difference in percentage points in the relative reduction of IRB loans where the respective cross-sectional dummy is equal to 1 and IRB loans where it is equal to 0 (columns 2-4), or the difference between IRB loans where the respective cross-sectional variable is at its 75^{th} percentile and IRB loans where it is at its 25^{th} percentile (columns 1 and 5). Robust standard errors adjusted for clustering at the bank and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Log(loans)*					
	Bank capitalization		Loan size		Firm ROA	
	(1)	(2)	(3)	(4)	(5)	(6)
IRB loan × Bank equity ratio	2.117**					
	(1.039)					
IRB loan × High equity		0.046**				
		(0.020)				
IRB loan × High exposure			-0.152**			
			(0.063)			
IRB loan × Large loan				-0.130***		
				(0.044)		
IRB loan × Firm ROA					0.129***	
					(0.032)	
IRB loan × High ROA						0.023
						(0.018)
IRB loan	-0.102***	-0.064***				
	(0.030)	(0.018)				
Bank equity measure	0.368	0.040*				
	(0.451)	(0.020)				
Loan size measure			-0.161***	-0.156***		
			(0.054)	(0.018)		
Bank controls	YES	YES	—	—	—	—
Bank × IRB FE	NO	NO	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES
Observations	90,500	90,500	90,500	90,500	14,336	14,336
R-squared	0.003	0.004	0.028	0.056	0.363	0.363
Differential impact	3.1 %	4.7 %	–14.1 %	–12.2 %	0.8 %	—

Table 8:
Firm level outcomes

This table reports firm-level results for the full sample of 107,025 firms and for a matched sample of 7,778 firms. As before we collapse our data into single pre- and post-event time periods. The dependent variable is the change in the logarithm of a firm's total amount of loans around the event. $\overline{\textit{IRB loan}}$ gives the share of a firm's loans that are subject to IRB. The variable $\overline{\textit{IRB loan}}^*$ gives the share of a firm's loans received from IRB banks that are subject to IRB. For tests that include this variable the sample is restricted to firms that have at least one IRB loan and at least one SA loan from an IRB bank: i.e., firms for which $\overline{\textit{IRB loan}}^*$ takes values unequal to 0 or 1. The IRB impact at the bottom of the table gives the difference in percentage points in the reduction in lending between firms that have only IRB loans and firms that have only SA loans (columns 1-4), or firms where $\overline{\textit{IRB loan}}^*$ is at its 75^{th} percentile and firms where it is at its 25^{th} percentile (columns 5-8). Further, the bottom of the table presents coefficients on the IRB variables corrected for firm demand effects by applying the procedure described in Section 3.2. Robust standard errors adjusted for clustering at the main bank level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Log(firm loans)*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\overline{\textit{IRB loan}}$	–0.051***	–0.056***	–0.086***	–0.113***				
	(0.015)	(0.018)	(0.024)	(0.029)				
$\overline{\textit{IRB loan}}^*$					–0.099*	–0.117**	–0.097**	–0.078*
					(0.057)	(0.050)	(0.043)	(0.040)
Log bank assets		0.006***		0.003*		0.003**		–0.003
		(0.001)		(0.002)		(0.001)		(0.003)
Bank equity ratio		0.641*		–0.334		–1.509*		–0.537
		(0.335)		(0.510)		(0.913)		(2.001)
Bank ROA		–0.005		–0.019		–0.054		0.022
		(0.016)		(0.024)		(0.074)		(0.088)
Log firm assets			–0.008	–0.008			0.038***	0.036***
			(0.007)	(0.007)			(0.009)	(0.009)
Firm ROA			–0.062	–0.070			–0.134	–0.128
			(0.059)	(0.059)			(0.138)	(0.138)
Firm leverage ratio			–0.102***	–0.109***			–0.230**	–0.188
			(0.035)	(0.035)			(0.115)	(0.114)
Constant	–0.060***	–0.214***	0.020	–0.021	–0.118***	–0.125***	–0.545***	–0.475***
	(0.004)	(0.041)	(0.071)	(0.083)	(0.031)	(0.044)	(0.101)	(0.100)
Observations	107,025	107,025	7,778	7,778	7,159	7,159	1,575	1,575
R-squared	0.003	0.006	0.011	0.012	0.003	0.006	0.026	0.028
IRB impact	–5.1 %	–5.6 %	–8.6 %	–11.3 %	–3.9 %	–4.6 %	–3.8 %	–3.0 %
IRB effect adjusted for demand	–0.046	–0.051	–0.081	–0.108	–0.063	–0.080	–0.062	–0.041

Table 9:
Firm capital cost

The table examines how changes in a firm's capital cost over the event depend on the regulatory approach used for its loans. The dependent variable is the change in a firm's capital cost (defined as interest paid over total loans) between the pre- and the post-event period. The variable $\overline{\textit{IRB loan}}$ gives the share of a firm's loans that are subject to IRB. The variable $\overline{\textit{IRB loan}}^*$ gives the share of a firm's loans received from IRB banks that are subject to IRB. For tests that include this variable the sample is restricted to firms that have at least one IRB loan and at least one SA loan from an IRB bank: i.e., firms for which the variable $\overline{\textit{IRB loan}}^*$ takes values unequal to 0 or 1. Robust standard errors adjusted for clustering at the main bank level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Firm capital cost*			
	(1)	(2)	(3)	(4)
$\overline{\textit{IRB loan}}$	0.0020***	0.0017		
	(0.0008)	(0.0011)		
$\overline{\textit{IRB loan}}^*$			0.0011	0.0015
			(0.0062)	(0.0061)
Firm controls	YES	YES	YES	YES
Bank controls	NO	YES	NO	YES
Observations	4,977	4,977	1,273	1,273
R-squared	0.006	0.010	0.0044	0.0055

Table 10:
Loan-level robustness

The table contains placebo tests to control for pre-event trends as well as robustness tests regarding the event definition. Columns 1-4 present results that are similar to our main test but use alternative time horizons. The dependent variable is the change in the logarithm of loans between 2007 and 2008, between 2006 and 2007, and so on. Loans are classified as SA or IRB loans according to the regulatory approach used at the beginning of 2008Q1, the first quarter for which this information is available. As we can only include loans that exist at the beginning of 2008, the sample becomes smaller and smaller the further we go back in time. In column 5 we use the last two quarters of 2006 instead of the first two quarters of 2008 as the pre-event period. In column 6 we exclude all loans from German banks that had problems already in 2007. In column 7 we exclude all loans that were moved from SA to IRB throughout our sample period and restrict the sample to those firms that still have at least one SA loan and at least one IRB loan from different IRB banks. Bank controls are the same as in previous tables. Robust standard errors adjusted for clustering at the bank and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Log(loans)*						
	Placebo tests				Additional robustness tests		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	2007 vs. 2008	2006 vs. 2007	2005 vs. 2006	2004 vs. 2005	Shock definition	Excluding problem banks	Excluding switcher loans
IRB loan	0.014	–0.018	0.010	0.006	–0.057**	–0.031**	–0.045***
	(0.018)	(0.012)	(0.011)	(0.018)	(0.027)	(0.014)	(0.015)
Firm FE	YES	YES	YES	YES	YES	YES	YES
Bank controls	NO	NO	NO	NO	YES	YES	YES
Observations	30,293	22,925	18,147	14,970	16,504	23,209	17,895
R-squared	0.245	0.261	0.242	0.228	0.320	0.317	0.292

Table 11:
Actual changes in PD and lending

The table examines how loans are adjusted following a rise in the PD, and how the adjustment depends on the regulatory approach. The sample is restricted to loan-quarter observations for which we observe an increase in the PD attributed to a specific loan. The dependent variable is the difference between the logarithm of loans two quarters following the rise in PD and the logarithm of loans in the quarter of the rise in PD. In columns 1 and 2, the sample is restricted to loans that were moved from SA to IRB throughout our sample period. In columns 3 and 4 the sample is further restricted to loans for which we observe at least two increases in the PD, one when the loan was still subject to SA and another one when the loan had already been moved to IRB. The IRB impact at the bottom of the table gives the difference in percentage points in the reduction in lending between loans under IRB and loans under SA. Robust standard errors adjusted for clustering at the bank and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Log(loans) around the PD change*			
	(1)	(2)	(3)	(4)
IRB loan	–0.016***	–0.014*	–0.029**	–0.026**
	(0.005)	(0.008)	(0.012)	(0.013)
Constant	–0.023***			
	(0.008)			
Period FE	NO	YES	YES	—
Bank × Firm FE	NO	NO	YES	YES
Bank × Period FE	NO	NO	NO	YES
Observations	24,321	24,321	3,288	3,288
R-squared	0.000	0.009	0.431	0.491
IRB impact	–1.6 %	–1.4 %	–2.9 %	–2.6 %

Table 12:
Firm-level robustness

The table shows robustness tests for the firm-level results. In column 1, we replace the dependent variable obtained from the credit register with the difference in the logarithm of balance sheet loans as obtained from the Amadeus database. In column 2, the sample is restricted to firms for which aggregate loans in the credit register cover at least 75 percent of balance sheet loans obtained from the Amadeus database. In column 3, the sample is restricted to loans to firms that are larger (in terms of total assets) than the median firm in our sample. In columns 4 and 5, we apply a procedure similar to Ongena et al. (2012). We calculate the difference between balance sheet loans from Amadeus and aggregate loans in the credit register to obtain the remainder of loans for which we do not have information on the regulatory approach. We make two extreme assumptions regarding the regulatory approach used for these remaining loans to calculate adjusted $\overline{IRB\ loan}$ variables. First, we assume that they are all subject to SA (column 4), and second that they are all subject to IRB (column 5). Robust standard errors adjusted for clustering at the main bank level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Log(firm loans)*				
	(1) Balance sheet	(2) Above median coverage	(3) Large firms	(4) Remainder SA	(5) Remainder IRB
$\overline{IRB\ loan}$	–0.066**	–0.172***	–0.130***	–0.177***	–0.035**
	(0.026)	(0.026)	(0.033)	(0.028)	(0.017)
Bank controls	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES
Observations	6,651	3,251	3,889	6,297	6,297
R-squared	0.009	0.035	0.013	0.026	0.011

Table A.1:
Selected articles about the shock to the real sector in 2008

The table presents articles from the financial press that relate to the credit risk shock. The first column shows the date of publication, the second gives the source and the last column provides a critical quotation.

Date	**Source**	**Content**
22.05.2008	*Die Welt* "Business climate improve despite of financial crisis?"	"The German economy is not affected by the turbulence on financial markets and the crisis in the US. [...] 'The economy in Germany still rests on solid fundamentals', says Ifo-expert Klaus Abberger in Munich."
03.07.2008	*DPA* "Survey: Financial crisis hardly affected companies – There is no credit crunch"	"According to a survey, most companies in Germany are able to get credit, despite the financial crisis. [...] Hence, companies remain willing to invest."
06.10.2008	*Handelsblatt* "Pessimism on its all-time record"	"The financial affects the real economy. Experts' economic outlook is now very negative, according to the Sentix index. The index continued its downturn in October and is now at the lowest value since the beginning of measurement in 2002."
09.10.2008	*Handelsblatt* "Corporate bankruptcies are imminent in 2009"	"'The German economy is now in a downward spiral. Companies will suffer an increase of corporate bankruptcies in the next two quarters', said Siegfried Beck, Chairman of the Verband der Insolvenzverwalter Deutschlands (VID)."
14.10.2008	*Handelsblatt* "Bad outlook for the economy"	"Research institutes have clearly lowered their forecasts of economic growth for next year in Germany."
04.11.2008	*The Daily Telegraph* "Almunia warns of deep slump in eurozone"	"'The economic horizon has significantly darkened', said Joaquim Almunia, the EU's economics commissioner. Mr. Mayer (Deutsche Bank) said the German economy could contract by 1.5 percent next year."
11.11.2008	*Die Welt* "Bad outlook for international stock markets"	"This negative change in mood arrived very quickly in the last month: A majority of experts judged the outlook as neutral in September; in June they considered the outlook as more positive. Now, the weak economic dynamic abroad prevents the German economy from defying the financial crisis any longer."
13.11.2008	*London Evening Standard* "Shockwaves as Germany goes into recession"	"The global economy took a new battering today as Germany became the first major nation to officially enter recession. [...] The German slump is the deepest since 1996 and economists said it could get worse."
23.12.2008	*F.A.Z.* "Big recession expected"	"According to the IfW, Germany will face its worst economic crisis in 50 years."
29.12.2008	*F.A.Z.* "Economists failed in predicting the crash"	"A majority of experts predicted a contraction, but only a few warned of an economic crash. Many people alluded to risks, but nobody dared to think about a financial crisis causing a near collapse of the whole system which would cause the worst recession since World War II."

Table A.2:

Lending and regulatory approach—OLS

The table shows the same tests as in Table 3, using OLS instead of the FE estimation. The change in *Log(loans)* for a bank-firm relationship is the dependent variable. Columns 1, 4 and 7 restrict the sample to firms with multiple lending relationships as in Tables 3, so that we are able to compare the coefficients from the FE estimation with the coefficient from the OLS regression. As OLS does not rely on identification within the same firm, we include also firms with only one lending relationships (or with only IRB loans or only SA loans) in the remaining columns. The IRB impact at the bottom of the table gives the difference in percentage points in the reduction in lending between loans from the average IRB bank (for which *Share IRB* equals 0.62) and loans from an SA bank in columns 1-2, and the percentage difference between IRB and SA banks or loans in the remaining columns. Robust standard errors adjusted for clustering at the bank and at the firm level are reported in parentheses. Note: * indicates statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Dependent variable:	Δ *Log(loans)*								
	Test 1 IRB vs. SA banks			Test 2 SA loans of IRB vs. SA banks			Test 3 IRB vs. SA loans within IRB banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Share IRB	–0.058***	–0.030*		–0.030	–0.034				
	(0.020)	(0.017)		(0.034)	(0.026)				
IRB bank			–0.025*			–0.024			
			(0.014)			(0.015)			
IRB loan							–0.050***	–0.025***	–0.025*
							(0.016)	(0.010)	(0.013)
Portfolio share	0.198	–0.224	–0.231	0.354	0.224	0.205	0.211	–0.295	–0.312
	(0.197)	(0.200)	(0.198)	(0.232)	(0.217)	(0.203)	(0.249)	(0.225)	(0.232)
Log bank assets	–0.010**	–0.004	–0.003	–0.010***	–0.005**	–0.005*	–0.016	0.001	
	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.011)	(0.007)	
Bank equity ratio	–0.296	–0.341	–0.330	–0.246	–0.371	–0.350	0.471	0.025	
	(0.302)	(0.240)	(0.245)	(0.354)	(0.229)	(0.220)	(0.801)	(0.532)	
Bank ROA	–0.000	0.007	0.007	0.012	0.005	0.005	–0.104***	–0.007	
	(0.016)	(0.009)	(0.009)	(0.012)	(0.008)	(0.008)	(0.038)	(0.026)	
State bank	0.014	0.007	0.009	0.030*	0.026**	0.028**	–0.024	–0.008	
	(0.020)	(0.016)	(0.017)	(0.017)	(0.012)	(0.012)	(0.037)	(0.023)	
Cooperative bank	0.011	0.018	0.022	0.023	0.034***	0.037***	–0.035	–0.003	
	(0.020)	(0.015)	(0.015)	(0.020)	(0.013)	(0.014)	(0.022)	(0.017)	
Constant	0.213**	0.074	0.053	0.193**	0.092	0.080	0.394	–0.048	
	(0.107)	(0.079)	(0.077)	(0.076)	(0.058)	(0.061)	(0.314)	(0.187)	
Bank FE	NO	NO	NO	NO	NO	NO	NO	NO	YES
Observations	93,370	182,966	182,966	49,492	121,549	121,549	27,620	90,500	90,500
R-squared	0.005	0.006	0.006	0.003	0.003	0.003	0.003	0.003	0.008
IRB impact	–3.6 %	–1.9 %	–2.5 %	—	—	—	–4.9 %	–2.5 %	–2.5 %