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Central bank funding and credit risk-taking

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Non-technical summary

RESEARCH QUESTION

The broader liquidity support programs, which the European Central Bank (ECB) employed in order to counteract the consequences of the global financial crisis of 2007-2008 and the sovereign debt crisis of 2010-2012, went way beyond the operational scope of classical monetary policy in several directions. For example, the ECB extended the pool of eligible collateral and introduced a full allotment strategy. Most notably, in the framework of its long-term refinancing operations (LTROs), the ECB substantially increased the maturity spectrum of central bank refinancing, providing loans to banks in the euro area with a maturity of up to three years. In this paper, we examine the following question: How did the extended liquidity provisions affect credit risk-taking? Specifically, how does central bank refinancing affect banks' loan supply to borrowers with different ex-ante risk levels? In this regard, we focus on the effect of the maturity extension and explicitly differentiate between short-term and long-term central bank funding (CBF).

CONTRIBUTION

These non-standard refinancing operations motivated recent research to revisit the issue of how monetary policy affects bank lending. This strand of the literature shows that the interventions have been successful in increasing bank lending volumes, thus counteracting contractions in aggregate credit and investment. We contribute to this literature by investigating the quality composition of banks' loan portfolios. By explicitly differentiating between short-term and long-term central bank funding, our results also add to the literature on the implications of bank funding maturities for the risk-taking incentives of banks. Finally, we also contribute to the policy debate on adequacy of potential macroprudential instruments and the ex-post effects of the expansionary monetary policy.

RESULTS

Our analysis provides four main findings. First, we document that higher central bank funding is associated with higher bank loan supply, especially so to ex-ante riskier firms. Specifically, banks with larger volumes of CBF expand their lending to ex-ante riskier firms, where firm risk is measured by firms' interest coverage, leverage and size. Second, we show that, once banks utilize CBF, its risk-increasing effect does not depend on idiosyncratic bank characteristics, such as size, liquidity and capitalization. This finding is important from a policy perspective: As an expansionary monetary policy, by definition, intends to increase bank lending and risk-taking incentives, microprudential bank supervision has an even more prominent role in monitoring bank solvency. Yet, our result also have implications for macroprudential supervision, suggesting that the macroprudential surveillance of the banking sector and the choice of macroprudential instruments should not only place a special focus on specific bank types, but it should—instead—take the banking sector as a whole into account in order to minimize the over and above risk-increasing implications of an expansionary monetary policy. Third, we document that especially long-term CBF is associated with an increase in banks' loan supply to ex-ante riskier firms. Finally, we show that the documented shift in bank lending behavior is associated with an in-sample, ex-post deterioration of bank balance sheets, but also higher firm-level investment and employment. In this sense, our results are indicative of the typical trade-off of expansionary monetary policy: the goal of achieving positive real economic outcomes might come at the cost of potentially aggravated financial stability risk.

Nichttechnische Zusammenfassung

FRAGESTELLUNG

Um die Folgen der globalen Finanzkrise von 2007-2008 und der Staatsschuldenkrise von 2010-2012 einzudämmen, hat die Europäische Zentralbank (EZB) ihre operativen Möglichkeiten, Banken Liquidität zuzuführen, in mehrerer Hinsicht erweitert. So vergrößerte die EZB den Pool der in Frage kommenden Sicherheiten bei Offenmarktgeschäften und wechselte vom Zinstender- zum Mengentender-Verfahren mit Vollzuteilung. Darüber hinaus hat sie die Laufzeit ihrer langfristigen Refinanzierungsgeschäfte erheblich erhöht und Darlehen an Banken im Euroraum mit einer Laufzeit von bis zu drei Jahren vergeben. Das ist Anlass, um folgender Frage nachzugehen: Wie hat die expansive Liquiditätsbereitstellung durch die Zentralbank das Kreditangebot von Banken gegenüber Unternehmen mit unterschiedlichem Risikoprofil beeinflusst? In diesem Zusammenhang fokussieren wir uns insbesondere auf die Laufzeitverlängerung und unterscheiden zwischen kurz- und langfristiger Finanzierung durch die Zentralbank.

BEITRAG

Die nicht standardmäßigen Refinanzierungsgeschäfte der EZB haben eine neuerliche wissenschaftliche Debatte angestoßen, wie sich die Geldpolitik auf die Kreditvergabe von Banken auswirkt. Aktuelle Untersuchungen zeigen, dass die Maßnahmen der EZB erfolgreich einer Kontraktion der aggregierten Kreditvergabe entgegengewirkt haben. Unsere Studie ergänzt diese Ergebnisse, indem wir nicht nur die aggregierte Kreditvergabe, sondern insbesondere die Qualität der Bankkreditportfolios untersuchen. Durch die explizite Unterscheidung zwischen kurz- und langfristiger Zentralbankfinanzierung tragen unsere Ergebnisse auch zu einem besseren Verständnis bei, wie sich das Laufzeitenspektrum der Passivseite einer Bank auf ihre Risikoneigung auswirkt. Schließlich tragen wir auch zur Debatte über die Angemessenheit potenzieller makroprudenzieller Instrumente sowie über die ex-post-Effekte expansiver Geldpolitik bei.

ERGEBNISSE

Unsere Studie zeigt vier wesentliche Ergebnisse auf. Erstens dokumentieren wir, dass eine höhere Zentralbankfinanzierung sowohl mit höheren Bankkreditvolumen als auch Kreditrisiken in Zusammenhang steht. Banken erweitern ihre Kreditvergabe vor allem an riskantere Unternehmen, wobei wir in diesem Zusammenhang das Risiko von Unternehmen anhand ihrer jeweiligen Zinsdeckungs- und Verschuldungsquote sowie Größe messen. Zweitens zeigen wir, dass, sobald Banken Zentralbankfinanzierung nutzen, ihre Risikoneigung nicht von idiosynkratischen Bankcharakteristika wie der Größe und Kapitalisierung abhängt. Da eine expansive Geldpolitik per definitionem die Kreditvergabe und Risikobereitschaft der Banken erhöhen will, spielt die mikroprudenzielle Bankenaufsicht eine noch wichtigere Rolle bei der Überwachung der Zahlungsfähigkeit der Banken. Unser Ergebnis hat jedoch auch Auswirkungen auf die makroprudenzielle Aufsicht, da die makroprudenzielle Überwachung des Bankensektors und die Wahl makroprudenzieller Instrumente nicht einen besonderen Schwerpunkt auf bestimmte Banktypen legen, sondern stattdessen den Bankensektor als Ganzes berücksichtigen sollte, um die potentiell risikoerhöhenden Auswirkungen einer expansiven Geldpolitik zu minimieren. Drittens dokumentieren wir, dass insbesondere langfristige Zentralbankfinanzierung mit einer Erhöhung des Kreditangebots der Banken an ex-ante-riskantere Unternehmen verbunden ist. Schließlich zeigen wir, dass die dokumentierte Veränderung des Bankkreditverhaltens mit einer ex-post Verschlechterung der Bankbilanzen, aber auch mit höheren Investitionen und Beschäftigung auf Unternehmensebene verbunden ist.

DEUTSCHE BUNDESBANK DISCUSSION PAPER NO 36/2020

Central Bank Funding and Credit Risk-Taking*

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Abstract

This paper examines the relationship between central bank funding and credit risk-taking. Employing comprehensive bank-firm-level data from the German credit registry during 2009:Q1-2014:Q4, we find that borrowing from the central bank is associated with rebalancing of bank portfolios towards ex-ante riskier firms. We further establish that this relationship is associated with the ECB's maturity extensions and that the risk-taking sensitivity of banks borrowing from the ECB is independent of idiosyncratic bank characteristics. Finally, we highlight that these shifts in bank lending might lead to an ex-post deterioration of bank balance sheets, but increase firm-level investment and employment.

Keywords: Monetary Policy, LTRO, Bank Lending, Credit Risk-Taking, Real Effects, TFP Growth

JEL classification: E44, E52, G21, O40

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1 Introduction

The broader liquidity support programs, which the European Central Bank (ECB)[1] employed in order to counteract the macroeconomic consequences of the global financial crisis of 2007-2008 and the sovereign debt crisis of 2010-2012, went way beyond the operational scope of classical monetary policy in several directions. For example, the ECB extended the pool of eligible collateral and introduced a full allotment strategy. Most notably, in the framework of its long-term refinancing operations (LTROs), the ECB substantially increased the maturity spectrum of central bank refinancing, providing loans to banks in the euro area with a maturity of 12, 18 and 36 months. These non-standard refinancing operations motivated recent research to revisit the issue of how monetary policy affects bank lending. Darracq-Paries and De Santis (2015) use panel VAR techniques to show that LTRO shocks increased credit supply, consistent with the finding of the traditional literature on the bank lending channel that expansionary monetary policy positively affects bank lending volumes (e.g., Kashyap and Stein, 2000, Kakes and Sturm, 2002; Gambacorta, 2005; Disyatat, 2011). While the result of a positive relation between non-conventional central bank liquidity uptakes and the volume of bank loan supply has been confirmed in Alves et al. (2016), García-Posada and Marchetti (2016), Carpinelli and Crosignani (2017) and Andrade et al. (2019), all of which use credit registry data from different (Southern) European economies, this literature has devoted less attention to the question of how central bank funding affects the composition of bank credit, in particular whether it shifts bank loan supply towards riskier firms, which is one goal of a central bank during periods of financial distress and known as the risk-taking channel of monetary policy (Jiménez et al., 2014; Ioannidou et al., 2015).

Two exceptions in this respect are the studies of Carpinelli and Crosignani (2017) and Andrade et al. (2019), who not only look at the volume, but also at the risk composition of banks' loan supply. Although the main finding of the former is that Italian banks mainly used central bank liquidity to buy domestic government bonds,[2] the study also finds that non-conventional monetary policy led to a disproportionate

[1] Strictly speaking, the Eurosystem—and not the ECB—is responsible for conducting monetary policy in the euro area. In this paper, however, we use ECB as a synonym for the Eurosystem to avoid confusions with the term European System of Central Banks.

[2] Buch et al. (2016) investigate sovereign bond holdings of German banks by using quarterly data from the Deutsche

increase in bank lending towards riskier firms in Italy. In contrast, Andrade et al. (2019) identify no such rise in credit risk-taking in the case of France. These opposing results call for further empirical research on the compositional shifts in bank loan supply towards riskier firms as a response to the ECB's recent monetary policy operations.

Theoretically, the link between central bank lending and credit risk-taking can work through various channels. Specifically, theory suggests that central bank liquidity injections, in the presence of bank agency problems, can generate adverse risk effects (i) by increasing aggregate liquidity in the banking system and reducing lenders' incentives to monitor their borrowers (Acharya and Naqvi, 2012), and (ii) by reducing interest rates, thereby inducing banks to search for yield (Rajan, 2006). In a frictionless world without uncertainty, short- and long-term liquidity provisions are equivalent in their effects on bank risk-taking because banks can rollover short-term loans indefinitely. However, if future central bank accommodation is uncertain, short-term liquidity exposes banks to rollover risk and, as a consequence, disciplines bank managers and reduces their risk-taking incentives (Calomiris and Kahn, 1991). Long-term liquidity provisions, in contrast, insulate banks in the long-run from the need to turn to private funding sources and from related rollover risk. We thus expect that the risk-augmenting effects of central bank funding are stronger if central banks provide funding with long-term maturity.

To empirically explore the relationship between the bank-level amounts of central bank funding and credit risk-taking, we employ comprehensive bank-firm-level data based on the German credit register over the period 2009:Q1-2014:Q4. "Although some degree of national differentiation in financial developments is a normal feature of a monetary union, heterogeneity in financial conditions across the euro area ha[d] increased significantly, as some countries ha[d] been affected more substantially by the financial crisis" (ECB, 2012). In this regard, Germany is an ideal laboratory for examining the effects of the expansionary monetary policy operations because the "non-standard measures were taken to support the functioning of the transmission mechanism, by bringing back liquidity to dysfunctional markets". Over

Bundesbank Securities Holdings Statistics for the time period from 2005:Q1 till 2010:Q4. They document that 31% of German banks do not invest in sovereign bonds at all. For all other commercial, public and cooperative banks the share of sovereign bonds accounts for 4% of their total assets, which is only a small fraction of their total portfolio. Thus, the sovereign bond holdings of German banks have quite different magnitudes than those of Italian banks.

time, the ECB's non-standard measures—while being open to banks in all countries—have been used more intensively in the financially troubled countries of the euro area (i.e., Ireland, Greece, Portugal and, subsequently, Spain and Italy). "The cross-country differences in the use of these measures largely reflect heterogeneity in the financial conditions across the euro area and have supported the effective conduct of the single monetary policy" (ECB, 2012). Therefore, in contrast to the recent literature (e.g., García-Posada and Marchetti, 2016; Acharya et al., 2017; Carpinelli and Crosignani, 2017; Jasova et al., 2018; Andrade et al., 2019), our analysis does not evaluate whether the expansionary policies achieved their intended targets in terms of restoring monetary policy transmission overall, and especially in the crisis regions of the euro area; instead, it explores the risk-taking channel of those policies in a country that was not "hit by a severe recession that aggravated problems in public finances and adversely affected banks' balance sheets" (ECB, 2012). That is, all monetary policy instruments are conducted to achieve price stability. However, not all of those affect the bank lending and risk-taking channel the same in regions less affected by the economic fundamentals triggering those measures. Hence, examining the effects of the ECB's refinancing operations on German banks, in turn, allows us to identify and to differentiate between the bank lending and risk-taking channel of those policies in an exogenous setting.

An empirical challenge when examining the effects of central bank funding is that the amounts of CBF on banks' balance sheets are endogenous to banks' lending behavior. We thus pursue an instrumental variable regression to isolate the exogenous component of central bank funding and to identify the effect of CBF on credit risk-taking. Specifically, we employ banks' pre-crisis exposures to industries and countries most affected by the global financial crisis as instruments for CBF. As we will show, both variables are relevant predictors of CBF (because for banks with higher such exposures the availability of interbank borrowing is limited, which is replaced by central bank funds) and at the same time they are likely to fulfill the exclusion restriction. We further, following the standard approach in the credit register literature, restrict our sample to firms with multiple bank relationships and include firm-time fixed effects. Thus, we examine whether a firm which borrows from several banks experiences the highest credit growth from those banks with the most significant amounts of CBF on their balance sheets. Since this

comparison is across banks for the same firm, firm-specific demand shocks are absorbed by the firm-time fixed effects and we are able to identify credit supply side effects (Khwaja and Mian, 2008). We also include bank-time fixed effects in our analysis to control for time-varying heterogeneity at the bank level, such as bank size and general risk-taking incentives (see, e.g., Jiménez et al., 2014).

Our analysis provides four main findings. First, we document that higher central bank funding is associated with higher bank loan supply, especially so to ex-ante riskier firms. In economic terms, a 1-pp increase in central bank funding is associated with an increase in banks' quarterly loan growth rate vis-à-vis ex-ante riskier firms (proxied by the interest coverage ratio) by 0.4-0.8 pp, which is 1.5-1.9 pp higher than the corresponding value of credit to safer firms. This is an economically significant effect, since the average credit growth rate in our sample is equal to -2.84%. Second, we show that, once banks utilize CBF, its risk-increasing effect does not depend on idiosyncratic bank characteristics, such as size, liquidity and capitalization. This finding is important from a policy perspective: As an expansionary monetary policy, by definition, intends to increase bank lending and risk-taking incentives, microprudential bank supervision has an even more prominent role in monitoring bank solvency. Yet, our result also have implications for macroprudential supervision, suggesting that the macroprudential surveillance of the banking sector and the choice of macroprudential instruments should not only place a special focus on specific bank types, but it should—instead—take the banking sector as a whole (i.e., all banks accessing CBF) into account in order to minimize the over and above risk-increasing implications of an expansionary monetary policy. Third, we document that especially long-term CBF is associated with an increase in banks' loan supply to ex-ante riskier firms. The attendant coefficient is 30% larger than the corresponding coefficient of total CBF in our benchmark specification. Finally, we show that the documented shift in bank lending behavior is associated with an in-sample, ex-post deterioration of bank balance sheets, but also higher firm-level investment and employment.

Our results contribute to the existing literature in several dimensions. Showing that the post-crisis monetary policy operations are associated with higher bank loan supply, we add to the literature on the bank lending channel and the real effects of financial intermediation (e.g., Jiménez et al., 2014; Ioannidou

et al., 2015; Cingano et al., 2016; Daetz et al., 2017; Acharya et al., 2018; Bentolila et al., 2018). Specifically, we contribute to the literature on the transmission of the ECB's recent monetary policy measures to credit supply (e.g., García-Posada and Marchetti, 2016; Carpinelli and Crosignani, 2017; Jasova et al., 2018; Andrade et al., 2019). As already mentioned, relative to these studies, our paper does not focus on overall credit supply but mainly on the quality composition of banks' loan portfolios, and explicitly differentiates between different maturities of central bank refinancing. In this sense, our study is also related to Todorov (forthcoming), who shows that the ECB's Corporate Sector Purchase Programme announcement increased prices, liquidity and debt issuance in the European corporate bond market, especially so for longer-maturity, lower-rated bonds, and for more credit-constrained, lower-rated firms. Our paper also connects to the recent literature investigating the impact of non-conventional US monetary policy, notably of the Federal Reserve's large-scale asset purchase programs, on bank lending volumes and risk (e.g., Di Maggio et al., 2016; Chakraborty et al., 2017; Darmouni and Rodnyansky, 2017; Kandrac and Schlusche, 2017; Kurtzman et al., 2017), which—by construction of those programs—is unable to differentiate between different maturities of central bank funds. We thereby finally speak to the literature on the implications of bank funding maturities for the risk-taking incentives of banks (e.g., Calomiris and Kahn, 1991; Diamond and Rajan, 2001; Huang and Ratnovski, 2011; López-Espinosa et al., 2012).

The remainder of our paper is organized as follows. In Section 2, we describe the data and introduce the empirical methodology. The main estimation results are presented in Section 3. In Section 4, we examine the effects of the different maturities of central bank funding. Section 5 explores the ex-post impact of central bank funding on bank and firm balance sheets. We perform several robustness checks in Section 6. Section 7 concludes.

2 Data and Methodology

2.1 The ECB's Refinancing Operations

In this section, we provide an overview of the ECB's refinancing operations, focusing on the long-term refinancing operations (LTROs), and to what extent they affected the German banking system. Prior to the global financial crisis of 2007-2008, the ECB's longest tender offered was three months. With the onset of the crisis, the ECB expanded the size and the maturity of its refinancing operations. Essentially, there have been three LTROs during our sample period of 2009:Q1-2014:Q4. The first LTRO with a maturity of twelve months and an interest rate of only 1% was settled in June 2009. It provided banks with an additional liquidity of 442 billion €. Against the backdrop of the European sovereign debt crisis, the ECB further extended the maturity of its refinancing operations. In December 2011, it announced its first LTRO with a three-year maturity and an interest rate of 1% and, in February 2012, it announced a second three-year refinancing operation that provided 800 euro area banks with an additional liquidity of 529.5 billion €.[3]

At the time when the first LTRO was settled, the German real economy has already started to recover from the global financial crisis and had an annualized real GDP growth rate of 0.3% in 2009:Q3—the first positive value since 2008:Q1. The annualized inflation rate (all items non-food and non-energy) in Germany has also recovered to a value of 1.3%. The following two LTROs were mainly conducted to counteract the real economic implications of the European sovereign debt crisis. As the ECB (2012) states "[...] the refinancing operations, and in particular the three-year LTROs, have supported sovereign bond markets, as some banks decided to use part of the liquidity to buy government bonds". Again, Germany was largely unaffected by this crisis: the average inflation rate over the period 2011:Q4-2012:Q1, when the three-year LTROs were announced, was equal to 1.1%; in addition, real GDP growth reached a value of almost 0.7%. These facts suggest that, though the different LTROs were calibrated at the European level to restore monetary policy transmission, to stabilize credit supply and to increase aggregate

[3] A detailed description of the respective refinancing operation, including the amounts alloted and the number of bidders, can be found on the following ECB website: https://www.ecb.europa.eu/mopo/implement/omo/html/top_history.en.html.

inflation rates, they were triggered above all by the weak macroeconomic fundamentals in the euro area periphery. Examining the effects of the ECB's refinancing operations on German banks, in turn, allows us to identify and differentiate between the bank lending and risk-taking channel of those policies in an exogenous setting.

2.2 Data

We construct a unique bank-to-firm-level data set at quarterly frequency, containing information on German bank lending behavior over the period 2009:Q1-2014:Q4. The main source of this data set is the Deutsche Bundesbank's credit register that comprises broadly defined bank-firm-level exposure, including traditional loans, bonds, off-balance sheet positions and exposure from derivative positions. Financial institutions in Germany are required to report to the credit register if their exposure to an individual borrower or the sum of exposure to borrowers belonging to one hypothetical borrower unit has at least once exceeded a threshold of 1 million € during the reporting period.[4] A borrower unit comprises legally and/or economically independent borrowers that are legally and/or economically highly connected to each other, e.g., due to (major) ownership relations (>=50%), profit transfer agreements etc. Consequently, the actual reporting threshold is distinctively lower. On average, the German credit register captures about two thirds of German bank loans.

We supplement this credit registry data with supervisory information on bank balance sheets (e.g., banks' stock of central bank funding, total assets, profitability, liquid assets, equity, non-performing loans, loan loss reserves). As Bundesbank data about non-financial borrowers is scarce and limited to general information, such as a company's industrial sector and the location of its head office, we also match firm-level accounting variables to our data set, provided by Bureau van Dijk's Amadeus database. This match is non-trivial because the German credit register and the Amadeus database do not share a common identifier. To match firms from these databases, we rely on the following algorithm. First, we match by the unique commercial register number, when it is available. Second, for observations without

[4] Prior to 2014, this threshold was equal to 1.5 million €. However, as the actual reporting threshold is distinctly lower (see arguments below), this threshold reduction does not lead to jumps in our credit variable.

this identifier, we rely on Stata's reclink command, a module to probabilistically match records (Blasnik, 2010). In this step, we match firms either by their name and zip code or by their name and city with a minimum matching reliability of 0.99. Third, we match firms that are not matched in the first two steps by hand. All in all, we thereby matched 4,143 firms by the commercial register number, 23,010 firms by Stata's reclink command and 1,038 firms by hand, and this matched sample covers roughly one third of the aggregated exposure to German non-financial firms reported in the credit register.

We correct our sample for mergers between banks by creating a new separate bank identifier after the merger takes place. We further exclude non-commercial banks (e.g., investment funds and special purpose banks), as their reaction to the ECB's monetary policy is likely to differ from the behavior of commercial banks. After these adjustments, we obtain a sample of almost 800,000 bank-firm-quarter observations.

2.3 Econometric Specification

We examine the relationship between central bank funding and credit risk-taking estimating the following model:

$$\begin{aligned} \Delta EXPOSURE_{bft} &= \alpha_{ft} + \mu * CBF_{b,t-1} + \beta * (CBF_{b,t-1} * RISK_{f,t-4}) \\ &\quad + \theta * X_{b,t-1} + \varepsilon_{bft}, \end{aligned} \tag{1}$$

The dependent variable in equation (1) is the log change in the credit exposure of bank b to firm f between time t-1 and t.[5]

The main regressor is the one-quarter lag of the bank-level share of CBF, defined as the stock of central bank funding over total assets. Following the theoretical literature reviewed in the introduction, we further expect the effects of the recent monetary policy operations to be most distinct for long-term

[5]When this exposure is equal to 0, we also set the corresponding logarithm to 0. Otherwise, we would obtain many missing values (see Jiménez et al. (2014) for a similar strategy).

central bank funds. We thus also present specifications where we dis-aggregate total CBF into short-term (maturity of less than one year) and long-term (maturity of at least one year) central bank funds.

In addition, to focus on the effects of CBF on credit risk-taking, we interact these variables with several firm risk indicators, lagged by four quarters as the firm data come at annual frequency.[6] Our main firm-level risk measure is the interest coverage ratio (EBIT/interest expenses). A higher ratio indicates a better financial health and increases firms' ability to meet interest obligations from operating earnings, thus decreasing firms' probability of default. For instance, in its recent financial stability report, the IMF (2018) argues that interest coverage ratios have a strong monotonic relationship with firm risk and credit ratings. It is therefore widely used as a firm risk proxy in the empirical literature (e.g., Duchin and Sosyura, 2014; te Kaat, 2018; Acharya et al., 2019; Andrade et al., 2019). In addition to the interest coverage ratio, we provide robustness tests using the leverage ratio (debt/equity) and firm size (the logarithm of total assets) as further risk variables. Using these variables, we calculate firm risk dummies, which are equal to one if a firm's interest coverage or size is lower, and a firm's leverage is higher than the respective median in the same year and industry.[7] [8]

Due to the granularity of the credit register data we exploit, we further restrict our sample to firms with multiple bank relationships and include firm-time fixed effects, α_{ft}.[9] Thus, we examine whether one firm borrowing from several banks experiences the highest credit growth from those banks with the most significant amounts of CBF on their balance sheets. Since this comparison is across banks for the same firm, firm-specific demand shocks are absorbed by the firm-time fixed effects and we are able to identify credit supply side effects (see Khwaja and Mian, 2008).

X includes the following bank-level controls: bank size (the log of total assets), the loan-to-asset ratio, the return on equity, the ratio of liquid assets to total assets, the regulatory capital ratio (regulatory

[6]The results are qualitatively unchanged for alternative lag structures (e.g., eight- or twelve-quarter lags) or if we calculate a 'permanent' measure of firm risk calculated over the entire sample period to rule out the possibility that a firm's risk measure deteriorates only temporarily due to, for instance, a higher sensitivity to business cycle fluctuations.

[7]Our results are robust to alternative thresholds, e.g., if we define firms in the top 10% of the respective risk distribution risky.

[8]We use firm risk dummies instead of the continuous variables because the latter have significant standard deviations and can take extreme values so that our analysis would be affected by outliers (IMF, 2018).

[9]As the firm-level data is at annual frequency, it virtually does not make a difference whether we include firm-year or firm-year-quarter fixed effects.

capital to risk-weighted assets) and the share of non-performing loans relative to total loans. The choice of controls is consistent with other studies based on the German credit register (e.g., Behn et al., 2014; Bednarek et al., 2015; Behn et al., 2016), which find that smaller banks with lower loan-to-asset ratios, less (regulatory) capital and less non-performing loans increase their lending most significantly.

These bank covariates, however, only control for observable heterogeneity across banks. In order to control for unobservable time-varying heterogeneity at the bank level, in particular banks' general risk-taking sensitivity, our benchmark specification replaces the set of bank-level controls with bank-time fixed effects (α_{bt}), following Jiménez et al. (2014) and Behn et al. (2016), among others. The regression equation is then specified as follows:

$$\Delta EXPOSURE_{bft} = \alpha_{ft} + \alpha_{bt} + \psi * (CBF_{b,t-1} * RISK_{f,t-1}) + \varepsilon_{bft}, \tag{2}$$

The bank-time fixed effects absorb the overall effect of central bank funding (μ), but still allow an estimate of the interaction between bank-level CBF and the risk characteristics of borrowing firms. The standard errors are clustered at the bank-firm level to allow the observations to be correlated within bank-firm relationships.

2.4 Identification via Instrumental Variables

As banks simultaneously decide on lending volumes and funding modes, CBF is not exogenous with respect to bank lending behavior: banks might have higher incentives to demand CBF if they plan to increase their loan supply in general, and to riskier firms in particular. In order to overcome this endogeneity problem, we pursue an instrumental variable regression, proposing a new instrument for central bank refinancing at the bank level, which is unrelated to banks' lending behavior during the sample period of 2009-2014. Specifically, we instrument banks' CBF volumes by a pre-crisis proxy for asset quality—banks' 2006 exposure to the manufacturing, agriculture and mining industry normalized by banks' total credit exposure.[10] This choice of instrument is based on the literature on the dynamics of

[10]The results are robust to measuring banks' industry exposure for alternative pre-crisis years.

banks' interbank exposure, which argues that, especially during episodes of financial distress, the availability and the costs of interbank borrowing are sensitive to banks' asset quality. That is, banks with lower and more volatile asset quality receive less interbank credit and experience higher interest rate spreads (e.g., Afonso et al., 2011; Angelini et al., 2011; Bednarek et al., 2015), thus replacing private interbank funding with central bank loans.

As can be seen from Figure A.1 of the Appendix, the manufacturing, agriculture and mining industry were most adversely affected by the global financial crisis, i.e., they experienced the most significant drop in value added after 2008. In addition, the value added growth rates of these industries during and in the aftermath of the global financial crisis are characterized by higher volatility than the growth rates of other industries.[11] Therefore, banks with a high exposure to these industries experience a significant deterioration in and heightened uncertainty regarding their asset quality, which restrains their access to private funds and increases the incentives to use CBF. In addition, although these industries only experience short-term problems, the need to turn to central bank refinancing of banks with high exposure to these industries can be expected to be quite long-lasting, as interbank markets have essentially disappeared since the onset of the global financial crisis and banks accessing CBF during the crisis have continued to refinance themselves via the central bank even afterwards (ECB, 2018; Kim et al., 2018).

Table A.1 of the Appendix presents the estimates of regressions of CBF on the aforementioned instrument. The attendant results indicate that the pre-crisis exposure to the manufacturing, agriculture and mining industry are indeed valid instruments for central bank funding—the F-statistic testing the hypothesis that the coefficient on the instrument is equal to zero clearly exceeds the threshold of 10. In economic terms, a bank at the 95th percentile of the distribution of exposure to the manufacturing, agriculture and mining industry has an almost 1 pp higher share of central bank funding in the total balance sheet than a bank at the 5th percentile, which is non-trivial given an average central bank refinancing share of 1.19% in our sample (see Table 1). Overall, our strategy of instrumenting CBF is thus consistent with Carpinelli and Crosignani (2017), who approximate banks' dependence on central bank liquidity with the share

[11] As the manufacturing, agriculture and mining sector is more open to international trade, this evidence is consistent with di Giovanni and Levchenko (2009), who show that export dependent industries are more volatile.

of foreign wholesale funding, whose flow dried up during the global financial crisis and increased such banks' demand for central bank liquidity. Yet, we refine their strategy, proposing an instrument that is also able to predict private funding shortages of smaller banks without access to foreign wholesale funding and taking into account that especially banks with lower asset quality (and not wholesale dependent banks in general) experience restrictions in their access to private funds.

Although we explore the effects of CBF on bank lending behavior over the 2009-2014 period, we measure banks' exposure to the manufacturing, agriculture and mining industry time-invariantly for the year 2006. This is beneficial for at least two reasons. First, we thereby mitigate concerns related to reverse causality. Second, it strengthens the exclusion restriction of the IV regressions, since banks' asset quality in 2006 is less likely to have a direct effect on bank lending during 2009-2014. However, in the presence of relationship lending, bank-firm exposure is very persistent and, consequently, the exclusion restriction could be violated despite the time lag. For instance, relationship lending implies that banks over the 2009-2014 period might roll over credit to firms in the manufacturing, agriculture and mining industry that they also maintained a credit relationship with in 2006, in which case our instrument would have a direct effect on the dependent variable, and not only via higher central bank funding. In order to confirm the validity of the exclusion restriction, we also present a specification that abstracts from relationship lending by restricting the sample to new bank-firm relationships, i.e., relationships that did not exist prior to 2009.

In Section 4, we dis-aggregate total CBF into short-term and long-term central bank funds. For this purpose, we instrument short-term CBF by the aforementioned variable—banks' 2006 exposure to the manufacturing, agriculture and mining industry. In addition, we use banks' pre-crisis GIIPS exposure (again scaled by banks' total credit exposure), which includes the interbank, firm and sovereign exposure of a bank, as instrument for long-term CBF.[12] For at least two reasons, GIIPS exposure is a good

[12] One could argue that banks with higher GIIPS exposure are generally more prone to excessive risk-taking, thus violating the exclusion restriction of our instrument. However, our results are qualitatively unchanged if we scale GIIPS exposure by banks' total exposure to emerging market economies. Since, in this case, GIIPS exposure is scaled by another variable that potentially captures an increased risk-taking sensitivity, we are confident that our instrument for long-term CBF (GIIPS exposure/total credit exposure) does not proxy for banks' general sensitivity to excessive risk-taking. The attendant results are available upon request.

instrument for long-term CBF. First, it is also a proxy for poor asset quality. However, in contrast to exposure in the manufacturing, agriculture and mining industry, GIIPS exposure signals lower asset quality especially at the time when the sovereign debt crisis in South Europe intensified and the ECB reacted to the crisis by introducing its long-term refinancing operations (2011-2012). These banks thus react to difficulties of accessing private funding by demanding long-term refinancing from the central bank. Second, German banks with a large GIIPS engagement prior to the global financial crisis also reshaped their post-crisis business models by reducing complexity and scaling back activities in the South Europe, thus shifting their focus to the domestic market (Bednarek et al., 2019). As such reorganizations are costly in terms of time and short-term margins, such banks are more prone to secure their liquidity needs with long-term CBF. This conjecture is corroborated in column (3) of Appendix Table A.1: GIIPS exposure is not only intuitively, but also statistically, a strong predictor of long-term CBF, with a F-statistic well above 10.

2.5 Summary Statistics

Table 1 presents the definitions and descriptive statistics for the variables employed in our analysis. On average, German banks reduce their loan supply vis-à-vis German firms, indicated by the negative average growth rate of bank loan exposure (-2.84%). However, the 5th and 95th percentile of the distribution point to significant differences across bank-firm relationships. The average amount of CBF relative to total assets is equal to 1.19%. Yet, there are also several banks with substantial amounts of total CBF exceeding 6% of their total assets. For these banks, the relevance of long-term CBF is higher than the one of short-term CBF (3.99% vs 3.26%). Table 1 also shows that there is a large cross-bank variation in the exposure (i) to the manufacturing, agriculture and mining industry and (ii) to firms in Greece, Ireland, Italy, Portugal and Spain.

Turning to the set of bank-level controls, Table 1 indicates that the average loan-to-asset ratio is equal to 58.5%, the average liquidity ratio is equal to 20.9%, pre-tax operating income over equity has an arithmetic mean of 16.2%, the average regulatory capital to risk-weighted asset ratio is equal to 19.0%

Table 1: Summary Statistics of the Baseline Variables

	Unit	Observations			5*th*	Mean	95*th*	Description
		bank-time	*firm-time*	*bank-firm-time*				
Dependent Variable								
ΔEXPOSURE	%	-	-	839,423	-65.79	-2.84	57.53	The growth rate in credit from bank b to firm f
Bank-Level Variables								
CBF (TOTAL)	%	30,158	-	-	0	1.19	6.23	Stock of central bank funding/total assets
CBF (SHORT)	%	30,158	-	-	0	0.52	3.26	Stock of central bank funding with a maturity of less than one year/total assets
CBF (LONG)	%	30,158	-	-	0	0.67	3.99	Stock of central bank funding with a maturity of at least one year/total assets
EXPOSURE (INDUSTRY)	%	30,158	-	-	0	5.74	16.62	Banks' 2006 exposure to agriculture, manufacturing and mining/total exposure
EXPOSURE (GIIPS)	%	30,158	-	-	0	3.11	11.60	Banks' 2006 exposure to the GIIPS/total exposure
SIZE	ln	30,158	-	-	18.96	20.74	22.98	The logarithm of total assets
LOAN-TO-ASSET	%	30,153	-	-	28.63	58.46	81.20	Total loans to non-banks/total assets
LIQUIDITY	%	30,158	-	-	7.67	20.93	50.36	Liquid Assets/total assets
PROFITABILITY	%	29,432	-	-	2.95	16.19	40.84	Pre-tax operating income/equity
CAPITAL	%	29,309	-	-	11.79	18.96	28.37	Total capital (regulatory)/risk-weighted assets
NPL	%	27,844	-	-	0.44	3.90	8.60	Non-performing loans/total loans
LLR	%	27,844	-	-	0.11	0.98	2.16	Loan loss reserves/total loans
RISK DENSITY	%	29,127	-	-	28.61	50.70	71.60	Risk-weighted assets/total assets
Firm-Level Variables								
RISK (INTEREST)	0/1	-	52,290	-	0	0.50	1	Dummy=1 if EBIT/interest expenses<median in the same industry-year pair
RISK (LEVERAGE)	0/1	-	78,009	-	0	0.49	1	Dummy=1 if debt/equity>median in the same industry-year pair
RISK (SIZE)	0/1	-	86,576	-	0	0.50	1	Dummy=1 if total assets<median in the same industry-year pair
ΔEMPL	%	-	76,601	-	-22.05	4.27	40.55	Growth in the number of employees
ΔK	%	-	83,342	-	-39.59	14.15	87.53	Growth in fixed assets
ΔTFP	%	-	43,242	-	-0.41	-0.01	0.38	TFP growth by estimating a production function as in Wooldridge (2009)

ΔEXPOSURE is the log difference in credit volumes of bank b to firm f at time t. CBF (total) is the bank-level share of central bank funding in total funding. CBF (short) and CBF (long) are the shares of short-term (<1 year) and long-term (>=1 year) central bank funding over total assets. EXPOSURE (GIIPS) and EXPOSURE (INDUSTRY) is banks' credit exposure to the GIIPS or to the manufacturing, agriculture and mining industry, relative to the total bank exposure. We add the following bank covariates: size (log of total assets), total loans over total assets, liquid assets over total assets, pre-tax operating income over equity, total capital (regulatory) over risk-weighted assets, non-performing over total loans, loan loss reserves over total loans and risk-weighted assets over total assets. The risk dummies are equal to 1 if a firm's interest coverage or size is lower, and a firm's leverage is higher than the corresponding median in the same year and industry. ΔEMPL, ΔK and ΔTFP are firm-level growth in the number of employees, fixed assets and TFP.

Table 2: The Number of Banks and Observations by Banking Group

Bank Type	No. Banks	No. Banks with CBF > 0	Bank-Firm Observations
Big (Multinational) Banks	5	5	166,816
Head Institutes of Cooperative and Savings Banks	12	12	156,537
Smaller Private Banks	231	98	171,449
Savings Banks	434	358	230,680
Cooperative Banks	904	628	113,941
$\sum$	1,586	1,101	839,423

and non-performing loans on average are equal to 3.9%. In Table A.4 of the Appendix, we also depict the means of these variables separately for banks with and without central bank funding. It becomes apparent that banks accessing central bank funds are on average larger, have lower loan-to-asset ratios, returns on equity and capital ratios, as well as higher non-performing loans. This evidence is consistent with the rationale for our instruments presented in Section 2.4—banks with weaker balance sheet characteristics seem to have difficulties in accessing private funding and, as a consequence, borrow disproportionately more from the central bank. In Section 5, we also evaluate the ex-post effects of CBF on bank balance sheets. To this end, we also employ banks' loan loss reserves over total loans and risk density, defined as risk-weighted over total assets, as the dependent variables, which have means of 0.98% and 50.70%, respectively.

Finally, we also report the summary statistics for the firm-level variables. The firm risk dummies have average values close to 0.5, which is a consequence of their definitions. ΔEMPL, ΔK and ΔTFP are firm-level growth in the number of employees, capital stock and total factor productivity. These variables are employed in order to study real effects (see Section 5 for further details on their calculation and the empirical identification strategy). Their average values are equal to 4.3%, 14.2% and -0.01%, respectively.

In Table 2, we depict the number of banks in our sample, dis-aggregated into the different banking groups. It shows that, overall, we have more than 1,500 banks in our sample. Although most of the sample banks are either cooperative or savings banks, the largest banks (big/multinational banks, head institutes of cooperative and savings banks, private banks) have the highest representation in our bank-firm-level data because they maintain credit relationships with a larger number of firms. Table 2 also

shows that the majority of sample banks accesses central bank funds, independent of the specific banking group. That is, even regional banks (savings and cooperative banks), and not just a handful of large and multinational banks, in Germany borrow from the central bank.

3 Results

3.1 Baseline Results

In this section, we present the baseline estimation results with regard to the relation between CBF and the volume and riskiness of bank lending. Column (1) of Table 3 presents the results of a regression of credit growth on the shares of central bank funding (without interacting them with the firm risk dummies). The positive coefficient of CBF indicates that higher amounts of central bank funding lead to increased credit growth rates—a result that has already been established in the extant literature. We thus continue focusing on the composition of banks' loan portfolios by interacting CBF with the firm risk dummy presented in Section 2.

Whereas the estimate of CBF is statistically insignificant in column (2), the corresponding interaction term is positive and statistically significant at the 5% level. This result points to the existence of significant risk-taking effects of CBF: additional central bank liquidity does not increase lending to ex-ante safer firms (the estimate of CBF is insignificant and even negative); instead it is associated with higher credit supply to riskier firms. In economic terms, a 1-pp increase in central bank funding raises banks' quarterly loan growth rate vis-à-vis ex-ante riskier firms by 0.56 pp,[13] which is 1.5 pp higher than the loan growth rate of safer firms and non-trivial given that the average loan growth rate in our sample is equal to -2.84% (see Table 1). Note that, since we define firm risk in relative terms (i.e., firms are defined risky if their EBIT over interest expenses is lower than the median in the same industry and year), our results imply that banks especially expand credit to firms at the higher end of the risk distribution. However, given the good macroeconomic environment with relatively high growth rates and low interest rates, the full distribution of firm risk in Germany has shifted in a favorable direction during the sample period

[13] This is the sum of the coefficients CBF and $CBF * RISK$.

(Deutsche Bundesbank, 2018), so that our result does not necessarily imply immediate risks to financial stability. Instead, it might rather suggest caution for the case when a potential recession deteriorates aggregate conditions and thus moves up the whole distribution of firm risk. Yet, as we show in Section 5, banks experience an immediate balance sheet deterioration (higher non-performing loans, loan loss reserves and risk density), despite the favorable macroeconomic environment in Germany during 2009-2014.

Our instrumental variable (the 2006 bank-level exposure to the manufacturing, agriculture and mining industry) is time-invariant although bank-level central bank funding varies over time. An advantage of a time-invariant instrument measured before the sample period is that it mitigates concerns related to reverse causality. Yet, following the methodology proposed in Braggion et al. (2017), we also interact the time-invariant instrument with time dummies in the first stage. This procedure gives us an idea whether the effect of our instrument (i.e., the exposure to the manufacturing, agriculture and mining industry) on central bank funding varies over time and in which years this effect is stronger. Figure A.2 of the Appendix shows the estimated effects of our instrument on bank-level central bank funding, as well as the corresponding 99% confidence interval. It indicates that the point estimates are remarkably constant over time and that 2011:Q4 is the only quarter where the effect of our instrument on CBF is statistically insignificant. Thus, banks' exposure to the manufacturing, agriculture and mining industry are significant determinants of CBF during almost all quarters of our sample. The associated second-stage results are shown in column (3) of Table 3 and document that our previous estimates are robust to interacting the time-invariant instrument with time dummies. If anything, this procedure increases the economic and statistical significance of the main coefficients. In the remainder of this paper, we refrain from interacting our instruments with time dummies. The following results are, therefore, rather on the conservative side.

In order for the 2006 exposure to the manufacturing, agriculture and mining industry to be valid instruments, the exclusion restriction must be satisfied. Particularly, the pre-crisis industry exposure should have no direct effect on bank lending during 2009-2014, but only affect it via central bank funding (as a substitute for the restricted access of these banks to private funding). As argued in Section 2.4, this

Table 3: Baseline Results

	no risk interaction	*with risk interaction*	*time-varying instrument*	*new bank-firm relationships*	*benchmark (with bank-time FE)*
	(1)	(2)	(3)	(4)	(5)
	ΔEXPOSURE	ΔEXPOSURE	ΔEXPOSURE	ΔEXPOSURE	ΔEXPOSURE
CBF	0.742***	-0.922	-1.090*	-3.031*	-
	(0.26)	(0.57)	(0.57)	(1.75)	
CBF * RISK	-	1.482**	1.907***	3.449*	1.718**
		(0.70)	(0.67)	(1.94)	(0.75)
SIZE	-0.111***	-0.147***	-0.143***	-0.224***	-
	(0.04)	(0.06)	(0.06)	(0.08)	
LOAN-TO-ASSET	-0.017***	-0.021***	-0.021***	-0.018***	-
	(0.00)	(0.01)	(0.01)	(0.01)	
LIQUIDITY	-0.003	-0.037***	-0.037***	-0.054***	-
	(0.01)	(0.01)	(0.01)	(0.01)	
PROFITABILITY	0.002	-0.003	-0.002	-0.001	-
	(0.01)	(0.01)	(0.01)	(0.01)	
CAPITAL	-0.035***	-0.044***	-0.042***	-0.058***	-
	(0.01)	(0.01)	(0.01)	(0.02)	
NPL	-0.114***	-0.082**	-0.085**	-0.084	-
	(0.03)	(0.04)	(0.04)	(0.05)	
Firm-Time FE	YES	YES	YES	YES	YES
Bank-Time FE	NO	NO	NO	NO	YES
Observations	762,296	449,044	449,044	309,660	468,953
R^2	0.102	0.092	0.092	0.095	0.133

This table shows our baseline specification results. The dependent variable is the log change in the exposure of bank b to firm f at time t. The main regressor is the instrumented amount of central bank funding over total assets (column (1)) and its interaction with a firm risk dummy (equal to one if a firm's interest coverage is below the median in the same year/industry, columns (2)-(5)). In most regressions, we employ banks' 2006 exposure to the manufacturing, agriculture and mining industry as instrument. Only in column (3), we use the interaction of industry exposure and time dummies as instruments. We add firm-time fixed effects and the following bank controls: size (ln of total assets), total loans over total assets, liquid assets over total assets, pre-tax operating income over equity, total capital (risk-weighted) over total assets and non-performing loans to total loans. In column (4), we limit the analysis to bank-firm relationships that did not exist prior to 2007. In column (5), we replace the bank covariates with bank-time fixed effects. Standard errors are clustered at the bank-firm relationship level and shown in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

assumption could be violated in the presence of relationship lending, i.e., if banks (in the post-crisis period) roll over credit to firms that they also maintained a credit relationship with in 2006. To abstract from relationship lending and confirm the validity of the exclusion restriction, we next restrict the sample to new bank-firm relationships (that did not exist in the pre-crisis period). Column (4) indicates that CBF still raises banks' risk-taking incentives, as can be gauged from the statistically significant interaction term. Economically, a 1-pp increase in central bank loans raises the credit growth differential between riskier and safer firms by more than 3.4 pp, validating the identifying assumption of our IV regressions.

Across the specifications of columns (1)-(4), we find bank lending to be negatively associated with bank size, loan-to-asset ratios, liquidity, capital ratios and non-performing loans. Similar results on bank size and bank equity ratios are documented in Behn et al. (2014) employing German credit register data. A negative sign for bank capital ratios can be attributed to the fact that, during and in the aftermath of the different crisis episodes, banks maintained higher capital ratios mostly by deleveraging on their assets. Andrade et al. (2019) confirm our results on both loan-to-asset ratios and liquidy ratios by using the French credit register. Whereas the result that banks with currently higher loans on their balance sheets reduce their lending indicates a mean-reverting behavior, the result on the negative relation between liquid assets and loan supply is likely to reflect differences in business models. The coefficient of non-performing loans has a negative sign as expected, suggesting that banks with a lower quality of loan portfolios tend to reduce their lending. All of these bank covariates only control for observable heterogeneity across banks. In order to control for both observable and unobservable time-varying heterogeneity at the bank level, we next replace the set of bank-level controls with bank-time fixed effects. This specification, spelled out in equation (2), constitutes our benchmark regression. The attendant results, reported in column (5), document that the disproportionate effect of CBF on the increased loan supply to ex-ante riskier firms is robust to including bank-time fixed effects (with a t-statistic on the corresponding interaction between CBF and firm risk being equal to 2.29).

Summing up, the results of Section 3.1 show that, at least in a country with sound financial and economic conditions, there exists a risk-taking channel of non-conventional monetary policy. That is,

CBF significantly raises the average volume of bank loan supply and this increase in lending is driven by increased loan volumes channeled towards riskier firms. A general shift in the composition of bank portfolios towards ex-ante riskier firms in Germany has also been documented by Deutsche Bundesbank (2019).

3.2 Are the Results Driven by Certain Types of Banks?

In this section, we exploit the cross-sectional dimension of our data by examining whether our baseline results are driven by certain types of banks. We have already mentioned in Section 2.5 that, on average, banks borrowing from the ECB are different from those that do not access CBF, i.e., they tend to be larger and to have lower capitalization. In this section, we examine whether, among banks borrowing from the central bank, our result of increased lending to relatively riskier firms depends on idiosyncratic bank characteristics. The results of this exercise provide us with insights for a better understanding of the transmission channels of monetary policy. The results also derive indications on whether banking sector surveillance should monitor certain banks more intensively than others in the wake of expansionary monetary policy.

Following the recent literature on the impact of non-conventional monetary policy in the euro area (e.g., García-Posada and Marchetti, 2016; Carpinelli and Crosignani, 2017), we examine the interaction of CBF with the following observable bank characteristics: liquidity, capitalization and size.[14] For our analysis of credit risk-taking, the choice of these covariates is also justified by the theoretical literature, which argues that large, poorly capitalized and high-liquidity banks might be more prone to excessive risk-taking. For instance, due to "too-big-to-fail" guarantees, bank investors monitor large banks less intensively than smaller banks, thus raising large banks' incentives to invest in risky projects (Boyd and Gertler, 1993; Stern and Feldman, 2009; Hovakimian et al., 2012; Wheelock and Wilson, 2012; Kaufman, 2015). In addition, as shown by Hovakimian and Kane (1996), Holmstrom and Tirole (1997) and Duran and Lozano-Vivas (2014), poor bank capitalization is a proxy for excessive risk-shifting in-

[14] We also employed alternative bank characteristics, such as non-performing loans and profitability. All of the following results are robust.

centives, mainly because poorly capitalized banks do not fully internalize their risk of default. Finally, excessive bank risk-taking can also increase in bank liquidity, which shields loan officers from penalties associated with failed investments and, as a consequence, raises their risk-taking incentives (Acharya and Naqvi, 2012).

In order to test whether our baseline results are amplified by these bank characteristics, we interact our main variable of interest, the double interaction between CBF and firm risk, with bank dummies that are equal to one if bank liquidity and capitalization are above the median of the full sample distribution of liquidity ratios and capitalization, respectively, and if bank size is in the top 5% of the full sample distribution of total assets.[15] [16]

Columns (1)-(3) of Table 4 indicate that our baseline results are independent of the different bank characteristics, as can be gauged from the statistically significant double interaction CBF*RISK and the insignificant triple interaction between CBF, RISK and the respective bank dummy. These results suggest that our baseline results are not driven by the implications of "too-big-to-fail" implicit bail-out guarantees or by risk-shifting incentives of the banking system, in which cases we should have obtained an overproportional effect for the largest, most weakly capitalized and highest-liquidity banks of our sample. Instead, our results indicate that central bank refinancing induces all banks borrowing from the ECB to increase their credit supply towards ex-ante riskier firms (i.e., firms with higher interest expenses), which is consistent with a general "search for yield" behavior.

Note again that Table A.4 of the Appendix shows that larger and more poorly capitalized banks are in general more likely to access CBF. At the same time, however, the uptake of central bank liquidity in Germany is not confined to large and multinational banks, but, instead, a large number of small and regional banks also accesses CBF (see Table 2). This fact combined with the evidence of this section that the risk-taking sensitivity of banks borrowing from the ECB is independent of idiosyncratic bank features are important from a policy perspective by calling also for macroprudential, instead of

[15] The results are robust to alternative thresholds and to defining the respective thresholds employing the year-by-year distribution of total assets, capitalization and liquidity.

[16] The deviating choice of the threshold for bank size is driven by the fact that the largest 5% of banks (about 60 banks) are overrepresented in our sample in terms of the number of bank-firm observations (see Table 2).

only microprudential, surveillance of the banking system. Specifically, in the light of this evidence, the surveillance of the banking sector should not only focus on specific banks, e.g., large or poorly capitalized banks (microprudential surveillance), but it should also take the banking sector as a whole into account (macroprudential surveillance) in order to analyze whether the risk-taking channel of the ECB's monetary policy has systemic implications.

Table 4: Exploring the Role of Different Bank Characteristics

	(1) ΔEXPOSURE	(2) ΔEXPOSURE	(3) ΔEXPOSURE
CBF * RISK	1.908**	1.440*	1.320*
	(0.82)	(0.81)	(0.77)
CBF * RISK * LIQUIDITY	-2.285		
	(2.70)		
CBF * RISK * CAPITAL		1.146	
		(2.91)	
CBF * RISK * SIZE			-0.023
			(1.89)
RISK * LIQUIDITY	2.803		
	(2.78)		
RISK * CAPITAL		-1.110	
		(3.39)	
RISK * SIZE			-0.682
			(2.42)
Bank-Time FE	YES	YES	YES
Firm-Time FE	YES	YES	YES
Observations	468,953	449,200	468,953
R^2	0.133	0.129	0.133

The table examines whether our baseline results are amplified by certain bank types. To this end, we interact CBF * RISK sequentially with bank dummies, equal to 1 if bank liquidity and capitalization are above the median of the distribution (columns (1)-(2)), respectively, and if bank size is in the top 5% of the distribution of total assets (column (3)). The dependent variable is the ln change in the exposure of bank b to firm f in quarter t. The key regressor is the instrumented amount of central bank funding over total assets, in its interaction with a firm risk dummy that is equal to 1 if firms' interest coverage is lower than the median in the same year and industry. We employ banks' 2006 exposure to the manufacturing, agriculture and mining industry as instruments. We also include firm-time and bank-time fixed effects. Standard errors clustered at the bank-firm level are reported in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4 Long-Term vs Short-Term Central Bank Funds

In Section 3, we have established a robust relationship between the bank-level amounts of central bank funding and greater lending to ex-ante riskier firms, which is largely independent of the different bank characteristics. In this section, we focus on the extended maturity of CBF as the main feature of the recent ECB's loose monetary policy measures, and examine whether bank risk-taking is predominantly driven by a higher share of long-term CBF in total assets. Such a finding would be consistent with the theoretical literature, which shows that only short-term funding serves as a disciplining device for bank managers; in contrast, the availability of longer-term funding reduces banks' exposure to rollover risk and increases banks' risk-taking incentives (Calomiris and Kahn, 1991). Jasova et al. (2018) provide empirical support for this mechanism by using the provision of long-term funding by the ECB as a natural experiment. They find that a reduction in rollover risk through lengthening of bank debt maturity has a positive and economically sizeable impact on bank lending and risk-taking.

Following this evidence, we continue differentiating between short-term central bank funds, with a maturity below one year, and long-term central bank funds, which have a maturity of at least one year. Following the discussion of instruments in Section 2.4, we instrument these variables with banks' exposure to (i) the manufacturing, agriculture and mining industry and (ii) Greece, Ireland, Italy, Portugal and Spain. In column (1) of Table 5, we only examine the effect of short-term CBF. The insignificant coefficient corresponding to the interaction between short-term CBF and firm risk indicates that central bank funds with a shorter maturity do not lead to increased credit risk-taking. In contrast, long-term CBF leads to a disproportionate increase in bank lending to ex-ante riskier firms (column (2)). This effect is not only statistically, but also economically significant: a 1-pp increase in long-term CBF raises the quarterly growth of banks' credit supply to riskier relative to safer firms by 2.03 pp. Thus, the economic effect is distinctively larger than the corresponding one of total CBF in our benchmark specification. This result is also robust to including short-term and long-term CBF simultaneously (column (3)), suggesting that our baseline results of Section 3 are driven by central bank funds with long-term maturity. We therefore document that the link between expansionary monetary policy and bank risk-taking is not only driven

by banks' substitution of private funding with central bank funds, but also by increasing the maturity of banks' central bank liabilities. This result is consistent with the theoretical literature arguing that agency problems between bank managers and investors are more severe the longer is the maturity of banks' liabilities (Calomiris and Kahn, 1991), as well as the empirical evidence of Jasova et al. (2018) and Todorov (forthcoming).

Table 5: The Different Effects of Long-Term vs Short-Term CBF

	(1) ΔEXPOSURE	(2) ΔEXPOSURE	(3) ΔEXPOSURE
CBF (SHORT) * RISK	1.287		-1.919
	(2.65)		(2.59)
CBF (LONG) * RISK		2.025**	2.216***
		(0.82)	(0.82)
Bank-Time FE	YES	YES	YES
Firm-Time FE	YES	YES	YES
Observations	468,953	468,953	468,953
R^2	0.134	0.133	0.155

This table presents the different effects of short-term (maturity of less than one year) and long- term (maturity exceeding one year) CBF. The dependent variable is the ln change in the exposure of bank b to firm f in quarter t. The key regressor is the instrumented amount of central bank funding in total assets, in its interaction with a firm risk dummy, equal to 1 if a firm's interest coverage is lower than the median in the same year and industry. We use banks' 2006 exposure to the manufacturing, agri - culture and mining industry, and GIIPS as instruments. We also add firm-time and bank-time fixed effects. The standard errors are clustered at the bank-firm level and shown in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5 The Ex-Post Effects of Central Bank Refinancing

Previously, we have shown that central bank funds is associated with an increased credit supply towards ex-ante riskier firms. This change in credit allocation, however, does not necessarily imply adverse effects on financial system stability and/or the real economy, since (i) a riskier credit allocation of banks does not need to lead to higher ex-post bank risk (ex-ante riskier firms do not need to default ex-post) and (ii) ex-ante riskier firms obtaining the additional credit may increase their investment, employment and total factor productivity. In Section 5, we therefore identify the ex-post effects of the ECB's post-crisis

monetary policy operations at the bank level (Section 5.1) and firm level (Section 5.2).

5.1 Ex-Post Effects on Bank Balance Sheets

We start investigating whether central bank refinancing also affects the ex-post risk of in-sample banks. To this end, we regress several bank risk variables on the share of central bank funding over total assets, which again is instrumented by banks' 2006 exposure to the manufacturing, mining and agriculture industry. Specifically, we employ the ratio of non-performing loans over total loans, loan loss reserves over total loans,[17] the risk-weighted regulatory capital ratio and risk density (risk-weighted over total assets) as bank risk proxies.[18] As can be seen from columns (1)-(4) of Table 6, higher CBF leads to an increase in non-performing loans, loan loss reserves and risk density. These effects are statistically significant and economically relevant: a 1-pp increase in CBF is associated with a 0.38 pp increase in the ratios of non-performing loans (given a mean of 3.9%), a 0.43 pp increase in loan loss reserves (mean=1%) and 4.89 pp higher risk density (mean=50.7%). In contrast, capital-to-asset ratios are not affected significantly. One reason for this insignificance might be the general trend towards higher capital ratios of German banks during our sample period (Deutsche Bundesbank, 2019).

5.2 Ex-Post Effects on Firm Performance

Section 5.2 studies the real economic (ex-post) implications of CBF at the firm level. For this purpose, we employ three key firm-level outcomes. Following Blattner et al. (2018), we make use of the log difference in employment (the number of employees) and fixed assets (as a proxy for capital investments) as the dependent variables. Further, as in Duval et al. (2017) or Doerr (2018), among others, we also calculate firm-level TFP growth, which we obtain by estimating a production function on firm-level data for each industry (2-digit NAICS code) separately, employing the approach of Wooldridge (2009). Specifically,

[17] We obtain similar results for loan loss provisions.

[18] For these regressions, the exclusion restriction of our instrument could be violated, as banks' 2006 exposure to industries most affected by the global financial crisis is likely to have a direct effect on bank risk, particularly non-performing loans. Yet, our results are robust to plain OLS regressions (results not reported).

Table 6: The Ex-Post Effects of CBF

	Bank-Level	*Bank-Level*	*Bank-Level*	*Bank-Level*	*Firm-Level*	*Firm-Level*	*Firm-Level*
	(1) NPL	(2) LLR	(3) RISK DEN.	(4) CAPITAL	(5) ΔEMPL	(6) ΔK	(7) ΔTFP
CBF	0.378***	0.429***	4.893***	0.278	0.009*	0.043**	-0.000
	(0.14)	(0.08)	(0.80)	(0.29)	(0.00)	(0.02)	(0.00)
Bank Controls	YES	YES	YES	YES	-	-	-
Time FE	YES	YES	YES	YES	YES	YES	YES
Industry FE	-	-	-	-	YES	YES	YES
Observations	27,364	27,364	28,872	29,046	73,115	79,398	40,952

This table examines the ex-post effects of CBF. In columns (1)-(4), the dependent variables are banks' non-performing over total loans, loan loss reserves over total loans, risk density (risk-weigthed over total assets) and total capital (regulatory) over risk-weighted assets. The key regressor is the one-year lag of CBF over total assets, instrumented with banks' 06 exposure to the manufacturing, mining and agriculture sector. In columns (5)-(7), the dependent variables are firm growth in employment, fixed assets and TFP. The key regressor is the predicted, weighted share of CBF over total assets of banks, which the respective firm borrows from (instrument as in Section 3). All of the estimations add time dummies. Industry fixed effects are added to the firm regressions. The bank regressions include the set of bank controls listed in Table 3. The robust standard errors are shown in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

we regress firm-level real value added (in logs) on labor input (log of the real wage bill) and capital input (log of the real book value of fixed assets), where all variables are winsorized at the 1% level before taking logs, value added and the wage bill are deflated by the two-digit industry price deflators from OECD STAN, and the capital stock is deflated by the price of investment goods. We then obtain TFP as the residual from this regression. Afterwards, these firm-level outcome variables are regressed on the predicted, weighted shares of CBF relative to total assets of those banks that a respective firm f borrows from.[19]

Table 6 indicates that firms borrowing from banks with higher CBF increase both their employment and investment, as can be gauged from the statistically significant coefficients on CBF in columns (5) and (6). The implied economic magnitudes are significant. Borrowing from a bank at the 95th percentile of the distribution of CBF, relative to borrowing from a bank at the 5th percentile, results in an additional annual 0.06 pp employment growth and an additional 0.27 pp capital stock growth.[20] In contrast, TFP growth is not affected significantly by central bank refinancing (column (7)). Particularly, firms that borrow from banks with higher CBF do not have ex-post higher TFP growth than firms borrowing from

[19]To obtain those predicted values, we again use banks' 2006 exposure to the manufacturing, mining and agriculture industry as instrument. The applied weights is the bank-firm-level exposure from the German credit registry.

[20]Given an average number of employees (nominal capital stock) in Germany during the sample period of 41 million (15 trillion euro), this results in an additional 24,600 employees and an additional 40.5 billion euro capital stock per year.

banks with lower values of CBF. All of these results are robust to controlling for different firm-level covariates, such as size, profitability, leverage etc. The results are available upon request.

Table 7: The Ex-Post Effects: Safer vs Riskier Firms

	Safer Firms			*Riskier Firms*		
	(1)	(2)	(3)	(4)	(5)	(6)
	ΔEMPL	ΔK	ΔTFP	ΔEMPL	ΔK	ΔTFP
CBF	-0.001	0.023	-0.0002*	0.024*	0.052***	0.0002*
	(0.01)	(0.01)	(0.29)	(0.01)	(0.02)	(0.00)
Time FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Observations	23,413	24,732	21,223	22,815	24,746	19,717

The table examines the ex-post effects of CBF, separately for safer (interest coverage dummy=0) and riskier firms (dummy=1). The dependent variables are firm growth in employment, fixed assets and TFP. The main regressor is the one-year lag of the predicted share of CBF over total assets of banks which a respective firm borrows from (instrumented as in Section 3). The regressions include time and industry fixed effects.Robust standard errors are shown in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As becomes apparent from Table 7, the previous results are driven by the sub-sample of ex-ante riskier firms, defined as firms with an EBIT over interest expenses lower than the median in the same industry and year, following the definition introduced in Sections 2-4. Particularly, while ex-ante riskier firms that borrow from banks with higher CBF increase their employment, investment and TFP, the impact on ex-ante safer firms is statistically insignificant (employment and investment) or even negative (TFP growth). This result is consistent with the previous evidence on the disproportionate increase in credit volumes for riskier firms.

6 Robustness Checks

In this section, we present several robustness checks. Particularly, we estimate our regressions via OLS, drop some type of banks and firms from our sample and employ alternative firm risk proxies.

In the first test, we estimate equation (2) via OLS. As can be seen from Table A.2, higher CBF still raises the loan volumes of ex-ante riskier firms disproportionately more (column (1)). While this effect is statistically significant at the 5% level, the economic magnitude of the OLS coefficient is distinctly

smaller than the corresponding effect in our IV estimations. This result suggests that bank-level central bank funding is clearly endogenous to other covariates and, as a consequence, needs instrumentation.

We continue dropping banks from our data set that Bundesbank classifies as big (multinational) banks (see Table 2 for the distribution of banks across bank types) because these banks can use funds raised by the parent bank or by branches in other (non-euro area) countries, insulating them to some extent from the effects of monetary policy in the euro area. Column (2) shows that this adjustment does not affect our coefficient estimates either.

As the next step, we drop firms in the manufacturing, agriculture and mining industry from the sample. This is important in order to provide further evidence on the satisfaction of the exclusion restriction in our analysis. Specifically, under the assumption that banks with higher 2006 exposure to the manufacturing, agriculture and mining industry have a general tendency of lending to these three industries, banks' pre-crisis exposure to these industries can have a direct effect on our dependent variable (credit growth) when firms in these industries are included in our sample. As a consequence, dropping firms in these industries allows us to circumvent this concern, and we are able to rule out a direct association between our instrument and the dependent variable. As can be seen from column (3) of Table A.2, even after excluding firms in the manufacturing, agriculture and mining industry, higher CBF is related to increased bank lending to ex-ante riskier firms. Again, the corresponding estimate is not only statistically but also economically significant: a 1-pp increase in CBF raises the quarterly credit growth rates of riskier firms by 2.8 pp more than those of safer firms. We thus provide further evidence for the validity of one of the main identifying assumptions underlying our IV analysis.

Finally, we use alternative proxies for firm risk—firms' leverage ratio and firm size.[21] Firms with higher leverage are more prone to asset substitution, undertaking more projects with a higher incidence to fail (e.g., Ben-Zion and Shalit, 1975; Jensen and Meckling, 1976; Carling et al., 2007). Also, these firms

[21] In the credit register, banks also provide probability of defaults (PDs) for their borrowers. However, only banks which comply to the IRB approach report those PDs and our sample of banks is much larger, including various banks applying the standard approach of capital regulation. Therefore, the distribution of PDs in the credit register is very skew. Nearly 80 percent of all borrowers have PDs close to zero (or in the range between 0 and 2%). Additionally, in their paper based on the German credit register, Behn et al. (2016) show that IRB banks tend to manipulate those PDs and systematically underpredict actual default rates.

are more likely to default because of their worse loss-absorbing capacity. Firm size (the logarithm of total assets) has also been shown to be an appropriate firm risk proxy, as larger firms are typically better established and more diversified (Carling et al., 2007; Paligorova and Santos, 2017). As in our previous regressions, we use these variables to calculate firm risk dummies, which are equal to one if a firm's size is lower, and a firm's leverage is higher than the respective median in the same year and industry. Table A.3 demonstrates that higher CBF is associated with a stronger increase in the credit supply to smaller and highly levered firms. The result that we obtain for smaller firms is consistent with by Garcia-Pasada and Marchetti (2016) and Jasova et al. (2018). As the economic magnitude of these effects is similar to our baseline estimates, we establish that those are robust to using alternative firm risk variables.

7 Conclusion

Following the global financial crisis of 2007-2008, central banks around the world have expanded the pool of monetary policy instruments and introduced long-term refinancing operations. For instance, the ECB provided central bank funding with a maturity of three years to banks in the euro area. However, while an extensive strand of the literature examines the effects of these monetary policy operations on the volume of bank lending, showing a positive association, results on the potential impact on the composition of banks' loan portfolios is to date underexplored and ambiguous.

Using a comprehensive bank-firm-level data set based on the German credit register during 2009:Q1-2014:Q4, we overcome this gap by examining the link between central bank funding and bank lending to firms with different ex-ante risk in an exogenous setting. Instrumenting banks' central bank funding by their pre-crisis exposure to industries and countries most affected by the global financial and euro area sovereign debt crisis, we find higher central bank funds to be associated with an increase in bank lending to ex-ante riskier firms. We further establish (i) that this effect is amplified by a longer maturity of central bank funding and (ii) that the risk-taking sensitivity of banks borrowing from the ECB is independent of idiosyncratic bank characteristics, such as size, liquidity or capitalization. Finally, we conclude that the documented shift in bank lending behavior might increase banks' ex-post risks (higher non-performing

loans, loan loss reserves and risk density), but at the same time raise firm-level investment and employment.

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Appendix

Additional Figures

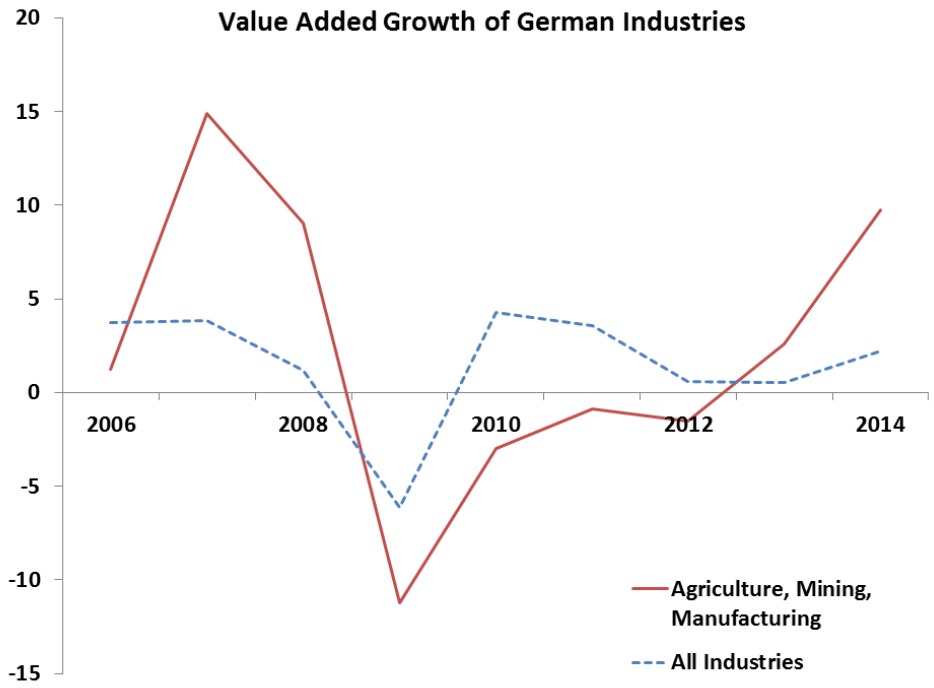

Figure A.1: This graphs shows the time series evolution of the average value added growth (in %) of all industries in Germany, as well as of the agriculture, mining and manufacturing industry only. The data are provided by the OECD.

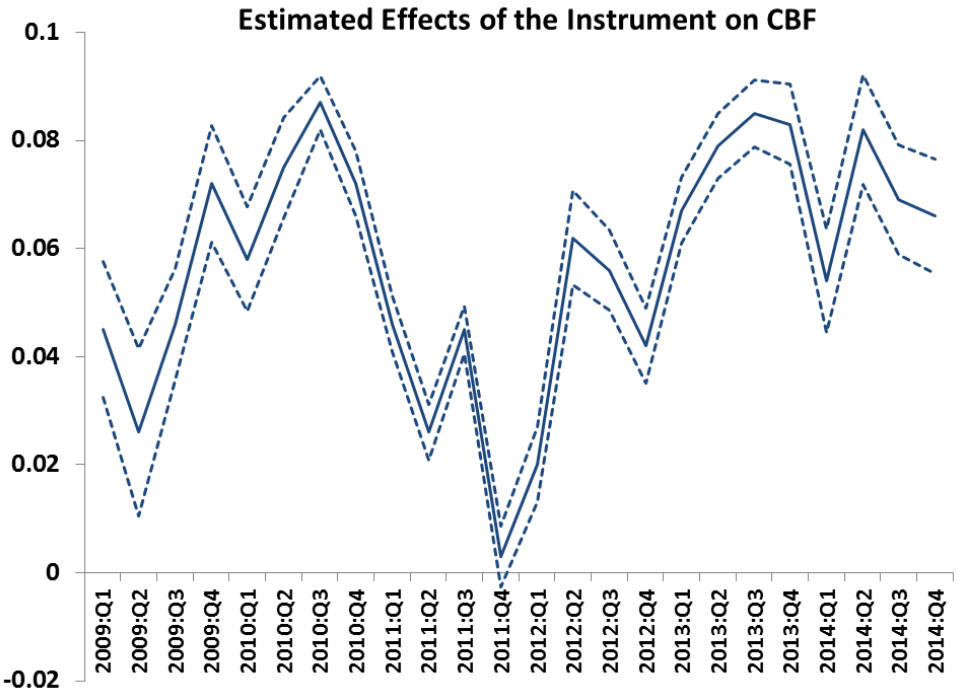

Figure A.2: This graphs shows the time series evolution of the estimated effect of the instrument—banks' 2006 exposure to the agriculture, mining and manufacturing industry—on bank-level central bank funding over total assets, as well as the corresponding 99% confidence interval.

Additional Tables

Table A.1: The Effect of the Instruments on CBF

	(1) CBF (TOTAL)	(2) CBF (SHORT)	(3) CBF (LONG)
EXPOSURE (INDUSTRY)	0.056***	0.021***	-
	(0.00)	(0.00)	
EXPOSURE (GIIPS)	-	-	0.007***
			(0.00)
Bank-Level Controls	YES	YES	YES
Firm-Time FE	YES	YES	YES
Observations	762,296	762,296	762,296
R^2	0.371	0.323	0.328
p (F-Statistic)	0.00	0.00	0.00

In this table, we show the estimates of a regression of central bank funding over total assets, CBF, (also disaggregated into two maturitry bands) on the pre-crisis exposure to the manufacturing, agriculture and mining industries and to GIIPS. We further add firm-time fixed effects and the bank controls of Table 1. The standard errors are shown in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: Robustness Test (1)

	OLS	*without largest banks*	*without mining, agriculture and manufacturing*
	(1)	(2)	(3)
	ΔEXPOSURE	ΔEXPOSURE	ΔEXPOSURE
CBF * RISK	0.180**	1.187*	2.783*
	(0.08)	(0.72)	(1.56)
Bank-Time FE	YES	YES	YES
Firm-Time FE	YES	YES	YES
Observations	468,953	364,488	277,298
R^2	0.134	0.165	0.153

This table presents the outcomes of several robustness checks. In column (1), we run ordinary least squares regressions. Column (2) drops multinational banks from the sample. In column (3), we drop from the analysis firms in the manufacturing, agriculture and mining sector. The dependent variable is the log change in the exposure of bank b to firm f in quarter t. The key regressor is the instrumented amount of central bank funding over total assets in its interaction with a firm risk dummy equal to 1 if a firm's interest coverage is lower than the median in the same year and industry.We employ banks' 2006 exposure to the manufacturing, agriculture and mining industry as instruments. We further add firm-time and bank-time fixed effects.Standard errors are shown in parentheses and clustered at the bank-firm level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: Robustness Test (2)

	(1) ΔEXPOSURE	(2) ΔEXPOSURE
CBF * RISK (LEVERAGE)	1.575**	-
	(0.76)	
CBF * RISK (SIZE)	-	2.680*
		(1.56)
Bank-Time FE	YES	YES
Firm-Time FE	YES	YES
Observations	614,919	601,069
R^2	0.140	0.142

In this robustness test, we use alternative firm risk proxies. Particularly, we define firms risky if their leverage is higher, or their size is smaller than the respective median in the same year /industry. The dependent variable is the log change in the exposure of bank b to firm f at time t. The key regressor is the instrumented amount of central bank funding in total assets, interacted with the aforementioned firm risk dummies. We use banks' 06 exposure to the manufacturing,agriculture and mining industry as instrument for central bank funds. We add firm-time and bank-time fixed effects and the standard errors are reported in parentheses and clustered at the bank-firm level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.4: Differences Between Banks With/Without CBF

	Mean (CBF=0)	Mean (CBF>0)	Difference between groups
SIZE	20.63	21.00	t=22.56
LOAN-TO-ASSET	59.09	56.97	t=-10.68
LIQUIDITY	21.01	20.76	t=-1.32
PROFITABILITY	17.50	13.53	t=-13.22
CAPITAL	19.54	17.42	t=-11.44
NPL	3.80	4.11	t=6.25

This table shows the means of the following bank-level controls for banks with/without central bank funding. Size (ln of total assets), the loan-to-asset ratio, liquid assets in total assets, the return on assets, the regulatory capital-to-risk weighted asset ratio and non-performing over total loans.