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To Whom Do Banks Channel Central Bank Funds?*

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Abstract

This paper examines the relationship between central bank funding and credit risk-taking. Employing bank-firm-level data from the German credit registry during 2009:Q1-2014:Q4, we find that banks borrowing from the central bank rebalance their portfolios towards ex-ante riskier firms. We further establish that this effect is driven by 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 show that these shifts in bank lending are associated with an increase in firm-level investment and employment, but also with a deterioration of bank balance sheet quality in the following year.

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 far 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. Consistent with the classical bank lending channel literature, numerous recent studies based on various methods ranging from panel VAR techniques (Darracq-Paries and De Santis, 2015) to microeconomic estimations exploiting credit registry data from different European economies (Alves et al., 2016; García-Posada and Marchetti, 2016; Andrade et al., 2019; and Carpinelli and Crosignani, forthcoming) have confirmed that bank lending volumes have been positively affected by the unconventional expansion of central bank funding. Far less attention has been devoted to the question whether these new monetary policy measures also lead to a shift in bank loan supply towards riskier firms. This effect, which is an important goal of a central bank during periods of financial distress and known as the risk-taking channel of monetary policy, is well-documented for standard monetary policy tools (Jiménez et al., 2014; Ioannidou et al., 2015). We are aware of only two studies that address this issue with regard to ECB's unconventional monetary policy: Carpinelli and Crosignani (forthcoming) find, using Italian data, that non-conventional monetary policy led to

¹Strictly 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.

a disproportionate increase in bank lending towards riskier firms in Italy, while Andrade et al. (2019), employing French data, identify no such rise in credit risk-taking. The discrepancy of these results hints that unconventional monetary policy might generate different results depending on underlying economic conditions. This motivates us to revisit the topic and examine a so far overlooked aspect of the ECB's policies: namely their impact on lending in an economy, which at the time of the introduction of most unconventional monetary policy measures, was in solid shape both in terms of real and financial economic conditions (i.e., Germany). This approach allows us not only to track the potentially divergent impact of uniform unconventional monetary policy in a monetary union with heterogeneous business cycles, but also to address the discussion on the potential costs for financial stability stemming from unconventional monetary policy measures, especially when they are not discontinued once an economy moves out of a severe contraction stage (see Bernanke (2012) for a detailed discussion).

More specifically, we employ comprehensive bank-firm-level data based on the German credit register over the period 2009:Q1-2014:Q4 to explore the impact of CBF on the riskiness of bank lending. As the ECB's non-standard measures were mainly conducted to bring back liquidity to dysfunctional markets in the euro area periphery (ECB, 2012), they were exogenous to the German financial system, making Germany with its sound financial and economic conditions during that episode an interesting setting for examining the side effects of non-conventional monetary policy in terms of greater credit risk-taking. As opposed to the aforementioned studies, we are able to examine explicitly to what extent the riskiness of bank lending depends on the maturity of central bank refinancing, since our data do not only cover the LTRO intervention period but also central bank refinancing operations with a shorter maturity. In addition, we quantify the ex-post impact of non-conventional monetary policy on financial stability and the real economy. Specifically, we gauge the effects of central bank funds on both

banks' balance sheets, i.e., non-performing loans, loan loss provisions and risk density (risk-weighted over total assets), as well as on firms' real outcomes, i.e., investment, employment and total factor productivity.

We document a significant shift in the composition of bank loan supply towards riskier firms, consistent with the evidence of Carpinelli and Crosignani (forthcoming) in the case of Italy. Our analysis also shows that this shift is amplified by central bank funding with long-term maturity. Short-term funds, in contrast, do not have a statistically significant risk-increasing effect. We further show some positive real effects of the unconventional measures by showing that the increased lending to firms results in higher firm-level investment and employment. However, we also illustrate that these effects come at the cost of an ex-post deterioration of bank balance sheets. In this sense, our results are indicative of the typical trade off of expansionary monetary policy: the goal of achieving positive real economic outcomes typically comes at the cost of potentially aggravated financial stability.

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 risk effects (i) by increasing aggregate liquidity in the banking system and reducing banks' incentives to monitor their borrowers (Acharya and Naqvi, 2012),² and (ii) by reducing interest rates, thereby inducing banks to search for yield (Rajan, 2006). If there is no uncertainty about rolling over of short-term debt, theory suggests no significant impact of CBF maturities. However, if banks are uncertain about the terms of future central bank funding options, accessing short-term central bank liquidity leaves banks exposed to rollover risk, while long-term liquidity provisions insulate them from the need to turn

²Note that, according to this theory, it does not make a difference whether the additional liquidity in the banking sector comes from private or public agents. Yet, as argued by Levine (2004), especially private agents can enforce market discipline, implying that the link between central bank funding and bank risk-taking in our empirical analysis might be particularly tight because central banks replace private agents in providing bank liquidity.

to private funding sources and from related rollover risk. Consistent with Calomiris and Kahn (1991) we thus expect short-term funding to have some disciplining effect on bank managers and reduce their risk-taking incentives. This implies that the risk-augmenting effects of central bank funding are stronger if central banks provide funding with long-term maturity.

When testing these hypotheses on the relation between the bank-level amounts of central bank funding and credit risk-taking empirically, the main challenge is that the amounts of CBF on banks' balance sheets are endogenous to banks' lending behavior. Specifically, banks that increase their lending to riskier firms might have a higher need for funding, part of which is satisfied via higher CBF. In order to overcome this endogeneity problem, we pursue an IV estimation, employing an instrument for central bank refinancing at the bank level, which is unrelated to banks' lending behavior during the sample period of 2009-2014. Specifically, consistent with Carpinelli and Crosignani (forthcoming), we employ banks' pre-crisis share of cross-border interbank borrowing as an instrument for CBF. As we argue below, this variable is a relevant predictor of CBF because banks with high exposure to the international interbank market are more affected by the dry-up of wholesale liquidity during the global financial crisis and the sovereign debt crisis that followed, thus replacing this dry-up with central bank loans. A further identification challenge is related to disentangling loan demand from loan supply. Following Khwaja and Mian (2008), we address this challenge by restricting 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. In order to control for time-varying heterogeneity at the bank level, such as bank size and general risk-taking incentives, we

also include bank-time fixed effects in our analysis (see, e.g., Jiménez et al., 2014).

Overall, our analysis provides four main findings. First, we document that higher central bank funding leads to increased bank loan supply towards ex-ante riskier firms, defined as firms with an Altman's Z-Score (Altman, 1968) below the median in the respective industry and year. In economic terms, a 1-percentage point (pp) increase in central bank funding raises the quarterly loan growth differential between ex-ante riskier and safer firms by 1.7-1.9 pp. Therefore, in contrast to Andrade et al. (2019), we document a significant shift in the composition of bank loan supply towards riskier firms. Note that, since we define firm risk in relative terms, our results imply that CBF is associated with banks expanding credit more to firms at the higher end of the risk distribution. However, given the good macroeconomic environment (relatively high growth and low interest rate environment), the full distribution of firm risk in Germany has shifted in a favorable direction during the sample period (Deutsche Bundesbank, 2018), so that our result does not necessarily imply immediate risks to financial stability. Instead, it especially suggests caution for the case when a potential recession deteriorates aggregate conditions and thus moves up the whole distribution of firm risk. In this case, banks with substantial CBF will be exposed to firms with higher absolute risk. Second, although banks borrowing from the ECB tend to be statistically different in terms of size and capitalization from those that do not access central bank funds, we show that, within the group of banks borrowing from the central bank, our result of increased lending to relatively riskier firms does not depend on idiosyncratic bank characteristics, such as size, liquidity and capitalization. This finding, combined with the fact that about two thirds of all banks in Germany during the sample period borrow from the ECB, is important from a policy perspective by calling for a broad, macroprudential surveillance of the banking system, instead of a microprudential surveillance that focuses mainly on specific banks, e.g., large or poorly capitalized banks. Third, we document that especially long-term CBF is

associated with an increase in banks' loan supply to ex-ante riskier firms, suggesting that the link between the new monetary policy instruments and 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. Finally, we show that the documented shift in bank lending behavior is associated with a higher share of non-performing loans, greater loan loss provisions, as well as increased risk density (measured by risk-weighted over total assets). Thus, the increase in lending to firms with ex-ante relatively riskier balance sheet characteristics seems to correlate with a deterioration of bank balance sheets, despite the favorable macroeconomic environment in Germany during 2009-2014. At the same time, however, we also find CBF to support the real economy by raising firm-level investment and employment.

Our results contribute to the existing literature in several dimensions. Apart from our main contribution to the aforementioned literature on the transmission of the ECB's liquidity support programs to the volume and composition of credit supply using credit registry data, we also speak to three other strands of the empirical literature on the ECB's non-conventional monetary policy. One strand is that relating the ECB's liquidity support programs to asset markets and corporate policies. While Crosignani et al. (2020) show that LTROs led banks to purchase high-yield and ECB eligible collateral securities so as to match the maturity of central bank loans, Acharya and Steffen (2015) and Drechsler et al. (2016) find that banks borrowing from the ECB increase their investments in distressed sovereign bonds. Another strand comprises studies on the impact of the more recent ECB liquidity injections (Targeted Long-Term Refinancing Operations, TLTROs) on lending and economic activity. Specifically, Benetton and Fantino (2018), Laine (2019), Afonso and Sousa-Leite (2020), Andreeva and García-Posada (2020) and Esposito et al. (2020) relate TLTROs to higher volumes and lower prices of credit. Balfoussia and Gibson (2016) show that TLTROs ultimately increase economic activity. A final strand in-

cludes papers that investigate the impact of other ECB measures, apart from its liquidity support programs studied in this paper, on bank lending behavior. Acharya et al. (2019) provide evidence that the ECB's OMT program induced banks with higher GIIPS exposure, by raising asset prices and bank equity, to increase loan supply, especially so to pre-existing low-quality (zombie) borrowers. Todorov (2020) gauges that the ECB's Corporate Sector Purchase Programme announcement increased prices, liquidity and debt issuance in the European corporate bond market, in particular for longer-maturity, lower-rated bonds, and for more credit-constrained, lower-rated firms. Arce et al. (2020) show that the ECB's Corporate Sector Purchase Programme induced Spanish firms to replace bank loans with bond issuance. Following this drop in bank loan demand, banks redirected credit to smaller, non-bond issuing firms.

Showing that the post-crisis monetary policy operations increase bank loan supply and economic activity, we further add to the general 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; Acharya et al., 2018; Bentolila et al., 2018). 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., Darmouni and Rodnyansky, 2017; Kandrach and Schlusche, 2017; Kurtzman et al., 2017; Chakraborty et al., 2020; Di Maggio et al., 2020), which—by construction of those programs—is unable to differentiate between different maturities of central bank funds. We thereby finally add 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; Jasova et al., 2018).

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 ex-post impact of central bank funding on bank and firm balance sheets. We perform several robustness checks in Section 5. Section 6 concludes.

2 Data and methodology

2.1. The German banking system

Germany's banking system comprises three pillars—commercial banks, savings banks and cooperative banks—with commercial banks representing the largest share in terms of total assets. The savings and cooperative banks are both geographically constrained and their business model is focused on deposit-taking and lending within their respective administrative district only. They are, however, represented supraregionally by their head institutes. This structure makes the German banking system relatively unique in Europe.

After France, the German banking system has the second largest amount of bank assets in the euro area. The banking sectors of France, Germany, Spain, Italy and the Netherlands together represent more than 80% of all banking assets of the euro area. There are some striking differences between the German and all other banking sectors in the euro area. In particular, the three-pillar-system with a large number of small, regional banks implies that the German banking system is less concentrated than that in other euro area countries, especially compared with Spain and the Netherlands. In addition, German banks are closer connected to the dynamics of the domestic economy, whereas banks in France, and especially in Spain and in the Netherlands, are more dependent on international real economic and financial conditions.

2.2. The ECB's refinancing operations

In this section, we provide an overview of the ECB's refinancing operations, especially focusing on the unconventional long-term refinancing operations (LTROs). 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%, providing 523 euro area banks with an additional liquidity of 489 billion €. In February 2012, it announced a second three-year refinancing operation at an interest rate of 1% 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. 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 pol-

³A detailed description of the respective refinancing operation, including the amounts allotted 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.

icy transmission, to stabilize credit supply and to increase aggregate 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 the potential side effects of the new monetary instruments in terms of credit risk-taking.

2.3 Data

We construct a 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 In this respect, note that a borrower unit comprises legally or economically independent borrowers that are connected to each other, e.g., due to (major) ownership relations ($\geq 50\%$), profit transfer agreements etc. That is, if two smaller firms that are economically or legally affiliated each have 0.5 million € credit outstanding, both loans have to be reported to Deutsche Bundesbank. Consequently, the actual reporting threshold in the German credit register is distinctively lower and, on average, the German credit register captures about two thirds of German bank loans. We use those data to calculate the dependent variable as the log change in the credit exposure of each bank-firm relationship.⁵ As can be seen from Table 1, German banks on average reduce their loan supply vis-à-vis German firms, indicated by the

⁴Prior to 2014, this threshold was equal to 1.5 million €.

⁵When this exposure is equal to 0, we also set the corresponding logarithm to 0 in order to maximize the number of observations, following Jiménez et al. (2014). As a robustness check, we also employ a hyperbolic sine transformation to overcome the issue of many zero-valued observations. Note that our data set does not include bank-firm relationships where firms never had a relationship with a particular bank.

negative average growth rate of bank loan exposure (-2.84%). The 5th and 95th percentile of the distribution illustrate that the dynamics of bank-firm relationships vary a lot.

We supplement the credit registry data with supervisory information on bank balance sheets to examine whether our results are stronger for specific bank types. These include bank size (the logarithm of total assets, where total assets are in euros),⁶ the ratio of liquid assets to total assets and the regulatory capital ratio (regulatory capital to risk-weighted assets). For the analysis of ex-post effects of central bank funding on bank balance sheets, which is the focus of Section 4, we also employ the share of non-performing loans relative to total loans, loan loss provisions over total loans and risk density, defined as risk-weighted over total assets. While Table 1 presents the summary statistics for these variables, Table A.1 of the Appendix depicts the means of some 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 capital ratios, as well as higher non-performing loans.

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 this identifier, we rely on Stata's relink 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

⁶Note that, when total assets are equal to 0, we also set the corresponding logarithm to 0 in order to maximize the number of observations.

Table 1: Summary Statistics of the Baseline Variables

Dependent Variable	Unit	Observations			5th	Mean	95th	Description
		bank-time	firm-time	bank-firm-time				
Δ EXPOSURE	%	-	-	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	%	30,158	-	-	0	2.72	11.91	Banks' 2006 cross-border interbank deposits to total assets
EXPOSURE (SHORT)	%	30,158	-	-	0	1.87	7.66	Banks' 2006 cross-border interbank deposits with a maturity of less than a year to total assets
EXPOSURE (LONG)	%	30,158	-	-	0	0.85	1.79	Banks' 2006 cross-border interbank deposits with a maturity of at least a year to total assets
SIZE	ln(euro)	30,158	-	-	18.96	20.74	22.98	The logarithm of total assets
LIQUIDITY	%	30,158	-	-	7.67	20.93	50.36	Liquid Assets/total assets
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
LLP	%	27,844	-	-	0.02	0.28	0.72	Loan loss provisions/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 (Z-SCORE)	0/1	-	52,934	-	0	0.59	1	Dummy=1 if Altman's Z-Score<median in the same industry-year pair
Δ EMPL	%	-	76,601	-	-22.05	4.27	40.55	Growth in the number of employees
Δ K	%	-	83,342	-	-39.59	14.15	87.53	Growth in fixed assets
Δ TFP	%	-	43,242	-	-0.41	-0.01	0.38	TFP growth by estimating a production function as in Wooldridge (2009)

Δ EXPOSURE is the log difference in credit volumes of bank b to firm f. CBF(TOTAL) is the bank-level share of central bank funding over total assets. 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 is the share of cross-border interbank deposits over total assets and EXPOSURE(SHORT) and EXPOSURE(LONG) are the cross-border interbank deposit shares with a maturity of less or more than 1 year, respectively. The bank variables are: size (logarithm of total assets), liquid over total assets, total capital (regulatory) over risk-weighted assets, non-performing over total loans, loan loss provisions to total loans and risk-weighted over total assets. The risk dummies are equal to 1 if a firm's interest coverage or Altman's Z-score is lower and a firm's leverage is higher than the corresponding median in the same year and industry. Δ EMPL, Δ K and Δ TFP are firm-level growth in the number of employees, fixed assets and TFP.

4,143 firms by the commercial register number, 23,010 firms by Stata's reblink 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. The distribution of total assets and the number of employees in our matched bank-firm data set is depicted in Appendix Table A.2, which shows that most firms in the sample are relatively large. For instance, the median (mean) number of employees is equal to 118 (5,555), with a 95th percentile of 10,055. Overall, according to the classification of the European Commission, 5.6% of the firms in our sample are micro firms, 16.5% are small (but not micro), 37.0% are medium-sized (and neither small nor micro) and 40.8% are large. Therefore, the results of this paper are to a large extent driven by large or medium-sized firms, which constitutes a limitation of our results in terms of external validity.

As we are particularly interested in whether more central bank liquidity increases bank lending towards riskier firms overproportionally, we use the Amadeus data to calculate Altman's Z-Score (Altman, 1968) as our main firm risk proxy. The choice of the Z-Score as our main firm risk measure is driven by the fact that it encompasses several risk dimensions (working capital, retained earnings, profitability, capitalization).⁷ In our regressions, we do not include the continuous Z-Score, but instead calculate a firm risk dummy equal to one if the Z-Score is smaller than the median in the respective industry and year, and to zero otherwise. The use of the dummy variable not only allows us to deal with outliers and with the extremely high standard deviation of this variable, but also enables us to examine how CBF affects the allocation of credit in terms of the relative riskiness of recipient firms. Last but not least, the use of the dummy allows to address potential non-linearities. A similar strategy has been employed by the

⁷In particular, we calculate the Z-Score as equal to $3.25 + 6.56 * \text{working capital} / \text{total assets} + 3.26 * \text{retained earnings} / \text{total assets} + 6.72 * \text{EBIT} / \text{total assets} + 1.05 * \text{equity} / \text{total liabilities}$, in line with Altman et al. (2017). We then calculate a three-year rolling average of the Z-Score to smooth the variable and prevent jumps. The results are similar, but estimated less precisely, when employing the Z-Score without moving averages. Note that Amadeus does not report data on retained earnings, which are part of the item "other equity". We hence use "other equity" in the above formula.

IMF (2018) and Farinha et al. (2019), among others.

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. Appendix Table A.3 depicts the number of banks in our sample after these adjustments, 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 (about 60%) because they maintain credit relationships with a larger number of firms. Appendix Table A.3 also shows that the majority of sample banks accesses central bank funds, independent of the specific banking group. That is, in Germany, even regional banks (savings and cooperative banks), and not just a handful of large and multinational banks, borrow from the central bank.

2.4. Econometric specification

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

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

The dependent variable in this equation is the log change in the credit exposure of bank b to firm f between time $t-1$ and t . The main regressor is the interaction between the lagged firm risk dummy introduced in Section 2.3 and the lagged 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 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.

Exploiting the granularity of the credit register data, we further restrict our sample to firms with multiple bank relationships and include firm-time fixed effects, α_{ft} .⁸ Thus, we examine whether one firm borrowing from several banks experiences the highest credit growth from those banks with the highest 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). In order to control for unobservable time-varying heterogeneity at the bank level, in particular banks' general risk-taking sensitivity, our specifications also include bank-time fixed effects (α_{bt}), following Jiménez et al. (2014) and Behn et al. (2016), among others. While the bank-time fixed effects absorb the linear effect of central bank funding, they 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.

2.5. 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 that increase their loan supply to riskier firms have a higher need for funding, part of which is likely to be satisfied with central bank loans. In order to overcome this endogeneity problem, we pursue an instrumental variable regression,

⁸As the firm-level data is at annual frequency anyway, it virtually does not make a difference whether we include firm-year or firm-year-quarter fixed effects.

employing an instrument for central bank refinancing at the bank level that is unrelated to banks' lending behavior during the sample period of 2009-2014. Specifically, we estimate a 2SLS regression using Stata's `ivreghdfe` command with a first-stage equation of the following form:

$$CBF_{b,t-1} * RISK_{f,t-1} = \alpha_{ft} + \alpha_{bt} + \beta * (INSTRUMENT_b * RISK_{f,t-1}) + \varepsilon_{bft}. \quad (2)$$

In this equation, our instrument for banks' CBF volumes is a pre-crisis proxy for their exposure to the cross-border interbank market—that is the amount of banks' cross-border interbank deposits relative to total assets in 2006. Consistent with Carpinelli and Crosignani (forthcoming), the intuition for the choice of this time-invariant instrument is that banks with high pre-crisis exposure to the cross-border interbank market are more affected than less exposed banks by the global dry-up of wholesale liquidity during and after the global financial crisis. These banks, therefore, have higher incentives to demand central bank funding in order to close any funding gaps.⁹

The tight positive association between our instrument and CBF is illustrated in Figure 1, which shows a bin scatter plot containing 100 quantiles of CBF.¹⁰ The positive correlation between the two variables is estimated to be roughly 51%. In unreported tests, we show that the strong positive correlation is valid for both the sub-samples of banks with high as well as such with low shares of interbank liabilities. More formal econometric evidence on the relevance condition will be presented with the first-stage estimates discussed in detail in Section 3, and with the first-stage F-statistics reported in each column of the regression tables shown in the following sections. Note here, however, that the F-statistics exceed the threshold of 10 in almost

⁹In previous versions of the paper, we employed banks' pre-crisis exposure to industries and countries most affected by the global financial crisis as instruments, arguing that banks with higher exposure had difficulties in obtaining wholesale liquidity, which they hence replaced by CBF. The results were similar.

¹⁰We are only allowed to present a bin scatter plot, not a full scatter plot, due to confidentiality reasons.

all specifications.

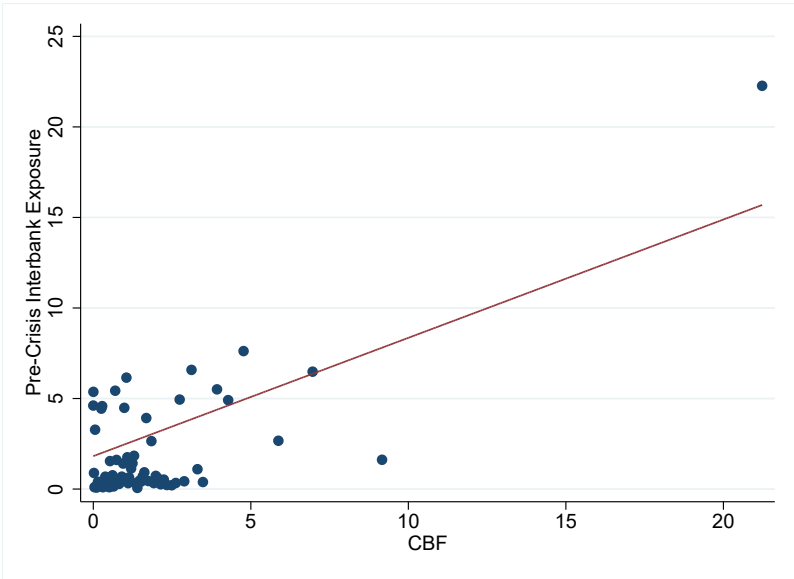


Figure 1: This graphs shows a bin scatter plot, containing 100 quantiles of central bank refinancing, between bank-level CBF, on average during 2009-2014, and the 2006 share of foreign interbank loans over total assets.

While the exclusion restriction of our instrument cannot be tested formally, we argue that our instrument is fairly exogenous since a bank’s reliance on the cross-border interbank market in the year 2006 is unlikely to affect lending during 2009-2014 through channels different from the volume of central bank funding these banks access. This is particularly the case since our regressions include bank-time fixed effects, which absorb any unobservable variation across banks and over time that might have been associated with alternative channels of how pre-crisis funding affects post-crisis lending, thus increasing the likelihood that the conditional exclusion restriction holds.

3 Results

3.1. *Baseline results*

In this section, we present the second-stage estimation results with regard to the relation between CBF and the riskiness of bank lending. We start presenting the results for our benchmark specification, instrumenting the potentially endogenous interaction between CBF and firm risk with the interaction between the pre-crisis foreign interbank exposure and firm risk. The attendant first-stage estimates can be found in Table A.3 and show that the first-stage F-statistics are equal to 41.2 with a point estimate of 0.031. Thus, the relevance condition underlying our IV approach is clearly met. The corresponding second-stage estimates of Table 2, column (1), show that the interaction between CBF and firm risk is positive and statistically significant at the 1% level. This result points to the existence of significant risk-taking effects of CBF: additional central bank liquidity increases the credit growth rates of ex-ante riskier firms by 1.79 pp more per year than those of safer firms, which is non-trivial given that the average loan growth rate in our sample is equal to -2.84%. Note, however, that, since we define firm risk in relative terms (i.e., firms are defined risky if their Z-Score 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 (Deutsche Bundesbank, 2018), so that our result does not necessarily imply immediate risks to financial stability. Instead, it rather suggests 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 4, banks experience an immediate balance sheet deterioration (higher non-performing loans, loan loss provisions and risk density),

despite the favorable macroeconomic environment in Germany during 2009-2014.

We next restrict the sample to new bank-firm relationships, i.e., relationships that did not exist in the pre-crisis period. This is important in order to examine whether the benchmark estimates are driven by banks increasing their lending to riskier firms that they already had a relationship with before the crisis (intensive margin) or by banks establishing new credit relationships with riskier borrowers (extensive margin). While the former could be interpreted as a sign of zombie lending, the latter can reflect the goal of the central bank to employ CBF to ease the credit constraints of hitherto constrained borrowers during periods of financial distress. Column (2) indicates that, also for new bank-firm relationships, CBF raises banks' risk-taking, as can be gauged from the statistically significant interaction term. In economic terms, a 1-pp increase in central bank loans now raises the credit growth differential between riskier and safer firms by 1.7 pp (as opposed to 1.8 pp in the benchmark specification). Therefore, CBF raises bank risk-taking not only at the intensive, but also at the extensive, margin.

Our instrumental variable (the 2006 bank-level cross-border interbank market exposure) 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 simultaneity. Yet, following the methodology proposed in Braggion et al. (2017), we also estimate a specification where the time-invariant instrument is interacted with the corresponding year-quarter dummies in the first stage. The associated second-stage results are shown in column (3) of Table 2 and document that our previous estimates are robust to interacting the time-invariant instrument with time dummies—the point estimate is virtually unchanged.

About 8% of the bank-firm relationship credit data in our sample are equal to zero. In order not to lose observations when calculating the dependent variable—the log-difference in credit volumes—we set the corresponding logarithm of credit volumes equal to zero, following

Table 2: Baseline Results

	<i>benchmark</i>	<i>new bank-firm relationships</i>	<i>time-varying instrument</i>	<i>IHS transformed</i>	<i>short- vs long-term funds</i>
	(1)	(2)	(3)	(4)	(5)
	Δ EXPOSURE	Δ EXPOSURE	Δ EXPOSURE	Δ EXPOSURE	Δ EXPOSURE
CBF * RISK	1.785*** (0.67)	1.728** (0.86)	1.784*** (0.67)	1.873*** (0.70)	-
CBF(SHORT) * RISK	-	-	-	-	-9.583** (4.54)
CBF(LONG) * RISK	-	-	-	-	7.114** (3.14)
Firm-Time FE	YES	YES	YES	YES	YES
Bank-Time FE	YES	YES	YES	YES	YES
Observations	472,920	324,804	472,920	438,472	472,920
First-Stage F-Statistic	42.5	23.8	42.5	44.1	8.1

This table shows our baseline specification results. The dependent variable is the log change in the credit exposure of bank b to firm f at time t . The main regressor is the bank-level share of central bank funding over total assets in its interaction with a firm risk dummy (equal to one if a firm's Z-score is below the median in the same year/industry). We use the interaction between banks' 2006 shares of cross-border interbank deposits to total assets and the firm risk dummy as instrument. We add firm-time and bank-time fixed effects. In column (2), we limit the analysis to bank-firm relationships, which did not exist prior to 2007. Column (3) interacts the shares of cross-border interbank deposits to total assets with time dummies in the first stage. In column (4), the credit volumes are IHS transformed before calculating their first differences. Column (5) distinguishes between short-term (<1 year) and long-term (≥ 1 year) CBF, using short-term and long-term interbank deposits as instrument in the first stage. Standard errors, clustered at the bank-firm level, are shown in parentheses.

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

Jiménez et al. (2014). As an alternative, we now present the estimation results when employing an inverse hyperbolic sine transformation before calculating the difference in credit volumes, as suggested by Bellemare and Wichman (2020). This transformation approximates the natural logarithm of that variable, but allows retaining zero-valued observations. As can be seen from column (4), our estimates even get statistically and economically more significant compared to the benchmark specification in column (1), which is evidence that our benchmark results are rather on the conservative side.

Finally, we focus on the extended maturity of CBF as the main feature of the recent ECB's monetary policy measures, and examine whether bank risk-taking is predominantly driven by a higher share of long-term CBF in total assets, consistent with Jasova et al. (2018), who use the provision of long-term funding by the ECB as a natural experiment and find that a lengthening of bank debt maturity has a significant impact on bank lending and risk-taking. To this end, we differentiate 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. As we now have two potentially endogenous variables, short-term and long-term CBF, we also need two exogenous instruments. We therefore employ the short-term cross-border interbank exposure (interacted with firm risk) as instrument for short-term CBF (interacted with firm risk) and the long-term cross-border interbank exposure as instrument for long-term CBF. As can be seen from the first-stage results presented in columns (2)-(3) of Table A.3, the interaction between firm risk and short-term (long-term) cross-border interbank exposure indeed has a positive impact on the interaction of firm risk and banks' shares of short-term (long-term) CBF. Column (5) of Table 2 contains the attendant second-stage results, which show that only long-term CBF has a positive and statistically significant impact on bank risk-taking. The corresponding interaction coefficient for short-term CBF is even negative, suggesting that it rather reduces bank risk-

taking. Note, however, that the first-stage F-statistic for this specification is slightly below 10 (see column (5) of Table 2), pointing to a potential weak instrument problem. In Section 5, we thus present the results of OLS regressions that differentiate between short-term and long-term CBF and, still, only long-term CBF increases bank lending towards riskier borrowers overproportionally. Therefore, although the effects of short-term vs long-term CBF on bank risk-taking are not fully identified (due to the first-stage F-statistic smaller than 10), this is evidence 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.

Summing up, the results of Section 3.1 show the existence of a risk-taking channel of non-conventional monetary policy in the case of Germany: CBF raises the average volume of bank loan supply disproportionately more for riskier than for safer firms. We also find that this result holds at the extensive margin and is driven by CBF with longer maturities.

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. As can be seen from Appendix Table A.1, 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, forthcoming), we examine the interaction of CBF with the following observable bank characteristics: liquidity, capitalization and size. Numerous theoretical studies suggest that these covariates are potentially related to credit risk-taking, in that smaller, well-capitalized and low-liquidity banks might be less 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). Excessive bank risk-taking can also decrease with lower bank liquidity, as liquidity shields loan officers from penalties associated with failed investments and, as a consequence, raises risk-taking incentives (Acharya and Naqvi, 2012). Finally, as argued by Hovakimian and Kane (1996), Holmstrom and Tirole (1997) and Duran and Lozano-Vivas (2014), higher bank capitalization can also reduce risk-shifting incentives, mainly because well-capitalized banks better internalize their risk of default, although there is also some evidence suggesting the opposite, namely that poor bank capital allows for less risk-taking simply because it decreases banks’ loss-absorbing capacity (Gambacorta and Mistrulli, 2004; Adrian and Shin, 2010; Kim and Sohn, 2017).

In order to test whether the risk-increasing effects established in Section 3.1 are attenuated by better capitalization, lower liquidity and smaller bank balance sheets, 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 or size, respectively, is in the lowest 25% of the in-sample distribution and capitalization is in the top 25% of the distribution.¹¹

Columns (1)-(3) of Table 3 indicate that our baseline results are independent of the differ-

¹¹The results are robust to alternative thresholds and to defining the respective thresholds employing the year-by-year distribution of total assets, capitalization and liquidity.

Table 3: Exploring the Role of Different Bank Characteristics

	(1)	(2)	(3)
	Δ EXPOSURE	Δ EXPOSURE	Δ EXPOSURE
CBF * RISK	1.791** (0.57)	0.520*** (0.20)	1.808*** (0.684)
CBF * RISK * LIQUIDITY	3.842 (5.80)		
CBF * RISK * CAPITAL		0.358 (1.345)	
CBF * RISK * SIZE			1.941 (6.12)
RISK * LIQUIDITY	-5.801 (9.08)		
RISK * CAPITAL		0.698 (1.63)	
RISK * SIZE			2.239 (5.72)
Bank-Time FE	YES	YES	YES
Firm-Time FE	YES	YES	YES
Observations	472,920	452,962	472,920
First-Stage F-Statistic	26.3	120.9	28.0

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 bank size are in the lowest 25% of the distribution and if bank capitalization is in the top 25% of the distribution. The dependent variable is the log change in the credit exposure of bank b to firm f in quarter t. We use the interactions between cross-border interbank deposits to total assets, the firm risk dummy and the respective bank characteristic as instrument for the triple interaction. We also include firm-time and bank-time fixed effects. Standard errors, clustered at the bank-firm level, are in parentheses.

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

ent 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. 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, which is consistent with a general “search for yield” behavior. Note again that Table A.1 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 A.3). This fact combined with the results of this section is important from a policy perspective by calling for a broad, macroprudential surveillance of the banking system, instead of a microprudential surveillance that focuses mainly on specific banks, such as large or poorly capitalized banks.

4 The ex-post effects of central bank refinancing

The previously documented change in credit allocation 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 be associated with 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, thus contributing to an improvement in economic dynamics and reducing the ex-post riskiness of credit recipients. In Section 4, by identifying the ex-post (i.e., one-year ahead) effects of the ECB’s post-crisis monetary policy operations at the bank level (Section 4.1) and firm level (Section 4.2), we finally evaluate the

impact of monetary policy on financial stability and the real economy.

4.1. Ex-post effects on bank balance sheets

We start identifying the correlation between central bank refinancing and the ex-post (one-year ahead) risk of 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 cross-border interbank exposure. Specifically, we employ the ratio of non-performing loans over total loans, loan loss provisions over total loans and risk density (risk-weighted over total assets) as bank risk proxies.

Table 4: The Ex-Post Effects of CBF

	<i>Bank-Level</i>	<i>Bank-Level</i>	<i>Bank-Level</i>	<i>Firm-Level</i>	<i>Firm-Level</i>	<i>Firm-Level</i>
	(1)	(2)	(3)	(4)	(5)	(6)
	NPL	LLP	RISK DEN.	Δ EMPL	Δ K	Δ TFP
CBF	1.009*	0.496**	6.687***	0.009*	0.042**	-0.000
	(0.54)	(0.21)	(2.14)	(0.01)	(0.02)	(0.00)
Bank Controls	YES	YES	YES	-	-	-
Time FE	YES	YES	YES	YES	YES	YES
Industry FE	-	-	-	YES	YES	YES
Observations	27,364	27,364	28,872	72,835	79,056	40,831
First-Stage F-Statistic	8.5	12.7	8.5	-	-	-

The table examines the ex-post effects of CBF. In columns (1)-(3), the dependent variables are banks' non-performing over total loans, loan loss provisions over total loans and risk density (risk-weighted over total assets). The key regressor is the one-year lag of CBF to assets, instrumented with banks' cross-border interbank deposits in 2006. In columns (4)-(6), the dependent variables are firm growth in employment, fixed assets and TFP. The main regressor in these specifications is the predicted, weighted share of CBF over total assets of banks that a firm borrows from. All estimations add time dummies. Industry fixed effects at the one-letter division level are added to the firm regressions. The bank regressions include the following set of bank controls: size (log of total assets), loans over assets, liquid to total assets, the return on equity, regulatory capital over risk-weighted assets and non-performing loans. The robust standard errors are shown in parenthesis.

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

As can be seen from columns (1)-(3) of Table 4, higher CBF is associated with an increase in non-performing loans, loan loss provisions and risk density. These effects are statistically significant and economically relevant: a 1-pp increase in CBF is associated with a 1.1 pp increase in the ratios of non-performing loans (given a mean of 3.9%), a 0.5 pp increase in loan loss provisions (mean=0.3%) and 6.7 pp higher risk density (mean=50.7%). This is evidence that

central bank refinancing might spill over to higher ex-post risk of banks, highlighting potential financial stability risk arising from the ECB's recent monetary policy measures.

4.2. Ex-post effects on firm performance

Section 4.2 studies the real economic (ex-post) implications of CBF at the firm level. This is important in order to evaluate whether the ECB's monetary policy was not only successful in boosting the real economy in the crisis-hit regions of Southern Europe, as shown by García-Posada and Marchetti (2016), Jasova et al. (2018) or Carpinelli and Crosignani (forthcoming), but also in countries less affected by the global financial and sovereign debt crisis, such as Germany. 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. (2020) 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, 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 investment goods price index. 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.¹²

Table 4 indicates that firms borrowing from banks with higher CBF increase both their

¹²To obtain the predicted values, we use our main estimation results of Section 3.1 (Table 2, column (1)). The applied weight is the bank-firm-level exposure from the German credit registry.

employment and investment, as can be gauged from the statistically significant coefficients on CBF in columns (4) and (5). 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 0.26 pp capital stock growth. In contrast, TFP growth is not affected significantly by central bank refinancing (column (6)). Particularly, firms that borrow from banks with higher CBF do not have ex-post higher TFP growth than firms borrowing from banks with lower values of CBF.

As becomes apparent from Table 5, the previous results are driven by the sub-sample of ex-ante riskier firms, defined as firms with a z-score lower than the median in the same industry and year, following the definition introduced in Section 2. 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 (for employment and investment) or even negative (for TFP). This result is consistent with the previous evidence on the disproportionate increase in credit volumes for riskier firms, which, as a consequence, seems to stimulate their real activities. These results indicate that these riskier firms have been facing credit constrains, which the unconventional ECB policy successfully resolves.

Table 5: The Ex-Post Effects: Safer vs Riskier Firms

	<i>Safer Firms</i>			<i>Riskier Firms</i>		
	(1) Δ EMPL	(2) Δ K	(3) Δ TFP	(4) Δ EMPL	(5) Δ K	(6) Δ TFP
CBF	-0.003 (0.01)	0.015 (0.01)	-0.0002* (0.00)	0.024* (0.01)	0.051*** (0.02)	0.0002* (0.00)
Time FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Observations	23,341	24,654	21,163	22,727	24,649	19,656

In this table, we investigate the ex-post effects of CBF, separately for safer (Z-Score 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, weighted shares of CBF to total assets of banks, which a firm borrows from. The regressions include time and industry fixed effects at the one-letter division level. Robust standard errors are shown in parenthesis.

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

Overall, these results provide evidence that, even in a country less affected by the financial and sovereign debt crisis, the ECB's monetary policy instruments had a sizable effect on investment and employment. In contrast, despite the positive effect on both firm-level input factors, firms' TFP growth did not increase, which suggests that the effect of CBF on real output growth is likely to manifest only in the short-run. In addition, for proper cost-benefit analysis of the impact of monetary policy in a country less affected by the financial crisis, such as Germany, the positive employment and investment effects should be weighed up against the deterioration of bank balance sheets, as documented in Section 4.1.

5 Robustness checks

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

In the first test, we estimate our model via OLS. As can be seen from Table A.5, 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 smaller coefficient size, however, is likely driven by an about six times larger standard deviation of actual CBF relative to the predicted values used in our IV regressions. Once we correct for the different standard deviations, the coefficient estimates of the OLS and IV regressions are quite similar. Column (2) further shows that the risk-increasing effects of CBF are driven by long-term, not short-term, CBF, consistent with the instrumental variable results presented in Section 3.

We continue dropping certain banks from our data set. Based on the classification used in Table A.3, column (3) of Table A.5 drops big banks and column (4) drops both big banks and the

head institutes of the savings and cooperative banks. Dropping those banks might be important because they are multinational and can therefore 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. In both specifications, the coefficient estimates are similar to our benchmark results.

Finally, we use two alternative proxies for firm risk—firms' interest coverage ratio, defined as the ratio of earnings before interest and taxes (EBIT) over interest expenses, and leverage. Higher interest coverage ratios indicate a better financial health and increase 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; Acharya et al., 2019; Andrade et al., 2019; te Kaat, forthcoming). Concerning leverage, more levered firms are known to be 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). They are also more likely to default because of their worse loss-absorbing capacity. As in our previous regressions, we use these variables to calculate firm risk dummies, which are equal to one if a firm's interest coverage ratio is lower, and a firm's leverage is higher than the respective median in the same year and industry. Table A.6 demonstrates that higher CBF is associated with a stronger increase in credit supply to firms with lower interest coverage and higher leverage, consistent with our baseline evidence on the risk-increasing effects of CBF. The estimates here, however, are estimated less precisely and only have a statistical significance at the 10% level.

6 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 up to 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, their impact on the composition of banks' loan portfolios is to date underexplored in the existing empirical literature. Also, the side effects of applying non-conventional expansionary monetary policy measures in times when recessions have been overcome are still mostly underexplored.

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 levels in an economy which, by the time of the introduction of these measures, had already recovered from the 2008-2009 recession. Using banks' pre-crisis exposure to the cross-border interbank market as instrument, we find higher central bank funds to increase 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 show that the documented shift in bank lending behavior is associated with an increase in banks' ex-post risks (higher non-performing loans, loan loss provisions and risk density), but at the same time increases firm-level investment and employment. Therefore, our results highlight the typical trade off of expansionary monetary policy that the goal of boosting the real economy commonly may come at the cost of potentially aggravated financial stability.

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Appendix: Additional Tables

Table A.1: Differences Between Banks With/Without CBF

	Mean (CBF=0)	Mean (CBF>0)	Difference between groups
SIZE	20.63	21.00	t=22.56
LIQUIDITY	21.01	20.76	t=-1.32
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 (log of total assets), liquid assets in total assets, the regulatory capital-to-risk weighted asset ratios and non-performing over total loans.

Table A.2: The Size Distribution of Sample Firms

	Mean	5th	Median	95th
Total Assets	3,096.4	0.6	19.0	5,831.3
Number of Employees	5,555.0	2	118	10,055

This table presents the size distribution (total assets in millions of euro and number of employees) of firms in our sample.

Table A.3: 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
Σ	1,586	1,101	839,423

Table A.4: First-Stage Estimates

	(1) CBF(TOTAL)*RISK	(2) CBF(SHORT)*RISK	(3) CBF(LONG)*RISK
EXPOSURE(TOTAL)*RISK	0.031*** (0.00)		-
EXPOSURE(SHORT)*RISK		0.007*** (0.00)	-0.003*** (0.00)
EXPOSURE(LONG)*RISK		-0.041*** (0.00)	0.008*** (0.00)
Bank-Time FE	YES	YES	YES
Firm-Time FE	YES	YES	YES
Observations	472,920	472,920	472,920
R^2	0.820	0.834	0.778

In this table, we show the estimates of a regression of the interaction between central bank funding over total assets (CBF, also disaggregated into their two maturity bands) and the firm risk dummy on the 2006 share of cross-border interbank deposits interacted with the firm risk dummy. We further add firm-time and bank-time fixed effects. The standard errors are shown in parentheses.

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

Table A.5: Robustness Test (1)

	<i>OLS</i>	<i>OLS</i>	<i>without big banks</i>	<i>without big banks and head institutes</i>
	(1)	(2)	(3)	(4)
	Δ EXPOSURE	Δ EXPOSURE	Δ EXPOSURE	Δ EXPOSURE
CBF * RISK	0.246*** (0.09)	-	1.295** (0.56)	1.432** (0.67)
CBF(SHORT) * RISK	-	0.165 (0.13)	-	-
CBF(LONG) * RISK	-	0.322*** (0.12)	-	-
Bank-Time FE	YES	YES	YES	YES
Firm-Time FE	YES	YES	YES	YES
Observations	472,920	472,920	367,663	279,218
First-Stage F-Statistic	-	-	56.9	48.4

This table presents the outcomes of several robustness checks. In columns (1)-(2), we run ordinary least squares regressions. Columns (3)-(4) drop big banks, and big banks as well as head institutes of cooperative/savings banks from the sample. The dependent variable throughout is the log change in the exposure of bank *b* to firm *f* in quarter *t*. The regressor is the interaction between bank-level CBF (partly disaggregated into the two maturity bands) and a firm risk dummy equal to 1 if a firm's Z-score is below the median in the same year and industry. Columns (3)-(4) instrument this interaction with the interaction between bank-level 2006 interbank deposits to total assets and the firm risk dummy. We 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.6: Robustness Test (2)

	(1) Δ EXPOSURE	(2) Δ EXPOSURE
CBF * RISK (INT. COVERAGE)	1.080* (0.64)	-
CBF * RISK (LEVERAGE)	-	3.383* (1.75)
Bank-Time FE	YES	YES
Firm-Time FE	YES	YES
Observations	468,953	659,205
First-Stage F-Statistic	48.6	19.7

In this robustness test, we use alternative firm risk proxies. Particularly, we define firms risky if their leverage is higher or interest coverage is smaller than the respective median in the same year and industry. The dependent variable is the log change in the exposure of bank *b* to firm *f*. The regressor is central bank funding over total assets interacted with the aforementioned firm risk dummies. We use banks' 2006 exposure to the cross-border interbank market interacted with the firm dummies as instruments. We add firm-time and bank-time fixed effects and the standard errors, clustered at the bank-firm level, are shown in parentheses.

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