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From financial to real economic crisis – Evidence from individual firm-bank relationships in Germany*

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Abstract:

What began as a financial crisis in 2007/2008 in the USA quickly became a massive crisis of the global real economy. We investigate the importance of the bank lending and firm borrowing channel in the international transmission of bank distress to real investment of firms. For the analysis we match individual firm and bank financial statements in Germany using information about individual lending relationships. The data include small and medium sized firms. Using IV estimations in first differences to eliminate firm- and bank-specific effects, we find that banks which experience losses from their proprietary trading activities cut back lending, and firms whose relationship banks reduce lending decrease real investment. Bank losses from proprietary trading during the crisis caused a decrease in the net real investment rate of their business customers by 20% through the reduction of credit supply, independent from demand effects. The effect is larger for firms unable to provide much collateral. We also document that firms can partially offset reduced credit supply by their relationship banks by resorting to self-financing and by establishing new bank relationships.

Keywords:

JEL Classification: D22; D92; G01; G31; H25; H32

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1 Introduction

The financial crisis of 2007/8 led to a significant decline in economic output and left the U.S. economy in an injured state. In particular, the crisis caused a significant drop in aggregate investment, resulting in a total capital stock well below its trend path (Hall 2010, 2014). Since capital adjustment is sluggish, this shortfall in real investment during the time of crisis has major consequences on the economy in the long run, potentially impeding output and employment for several years into the future.

There has been a vigorous debate about whether the U.S. financial crisis also propagated to the banking sector of other countries and about the role of multi-national banks in the transmission process (e.g., Popov and Udell 2012 and Allen et al. 2012). These studies show that the activities of bank subsidiaries outside the U.S. are affected by the parent bank's fragility, its losses on financial assets, and its reliance on interbank lending. Because of data restrictions, tracing these effects from the bank to the firm level, however, has turned out to be difficult. Thus, our knowledge about how the financial crisis of 2007/8 impaired the real economy outside the U.S. is still very limited. Though, understanding whether events such as the U.S. financial crisis affect the real economy in other countries through the bank lending and firm borrowing channel has important implications, both for the design of financial regulation and crisis management and for the modelling of financial crises. In particular, it is important to understand the implications of globalization in banking for firm investment and capital stock; both have been regarded as variables through which the financial crisis has the most enduring impact on growth of the post-crisis economy (Hall 2014).

The goal of this paper is thus to understand whether a substantial shock to the financial sector (as the U.S. subprime mortgage crisis of 2007/8) affects credit supply and firm investment behavior in a foreign country with stable economic performance—despite the fact that the real economy in Germany was not directly affected by the subprime mortgage crisis.

We dig deeper by also studying the kinds of firms which are affected most by a potential credit rationing and by assessing how firms can mitigate credit rationing in such situations.

We address these questions by focusing on the German economy, which is ideally suited to provide novel and substantive insights for various reasons. First, Germany is the largest single economy in Europe and the fifth largest economy of the world. Second, it did not undergo a housing market bubble in the 2000s; unlike in the U.S. or in other European countries there was no significant increase and rapid decline of German housing prices during that period. Third, Germany saw a period of stable economic performance with a record-low level of unemployment until 2008 so that we do not have to worry about negative domestic demand effects at the beginning of the financial crisis. Fourth, some of the German banks had large exposure to the U.S. subprime market and were substantially hit by the financial crisis (see, e.g., Bertaut et al. 2012).

Our empirical strategy proceeds as follows. We exploit a unique data base which contains financial statements at the level of the firm for the period 2004–2010 together with the financial statements of the bank(s) the considered firm has a lending relationship with. This allows us to study whether banks which were affected at the onset of the financial crisis because of their pronounced proprietary trading activities contract firm lending more relative to non-affected banks. We are able to distinguish the effect of credit supply from credit demand using an instrumental variable (IV) approach, where our instruments seize a bank's intensity of exposure to the U.S. financial crisis 2007/8. We then study whether a contraction in loan supply translates into lower investment rates by the firms that have a lending relationship with that bank. Our IV approach allows us to isolate the effect of credit supply by relationship banks from reductions in the firms' investment opportunities during the crisis. It also allows us to identify the bank lending channel, i.e., the causal transmission from bank distress to reduced firm borrowing and investment, isolated from the firm balance sheet channel, which occurs when an economic downturn devalues assets in the balance sheets of

the firms and thus their collateral and credit-worthiness. The extant literature has found it difficult to separate the bank lending channel from the demand side and from the firm balance sheet channel because of their simultaneity.

Our data set covers firms of all sizes, including small and medium sized enterprises, which are of major importance for the German economy. The exceptionally broad coverage benefits our analysis in two ways: First, the data allow us to identify the kinds of firms which are affected most, in particular in terms of size, age, capital intensity, and tangibility. This sheds light on the role of informational asymmetries in explaining the importance of relationship bank lending. Second, we can study the various adjustment channels which firms might use in order to mitigate credit rationing and which might vary with firm size, such as establishing new bank relationships and self-financing.

Our analysis yields five main empirical findings. First, banks with significant losses from proprietary trading activities and large exposure to the U.S. financial crisis 2007/8 cut back their loan supply in Germany. Banks operating multi-nationally thus propagated the U.S. financial crisis to the German economy. Second, we find that a contraction in overall loan supply by a firm's relationship bank(s) translates into lower firm borrowing. This suggests that relationship lending is important in Germany. Firms cannot fully substitute loans from a relationship bank with loans from other banks. These results are most pronounced for long-term loans. Third, firm investment rates respond to bank credit supply: if firms' relationship banks reduce their credit supply, firms have to cut back their real investment. Again, this result holds particularly true for long-term credit supply. As our instrumental variable approach purges any demand effects on the part of the firm from the regression, this response shows that shocks in the financial sector transmit to the real economy. A natural interpretation of this finding is that capital markets are imperfect. Fourth, smaller and younger firms and firms with a lower tangibility of assets tend to be more strongly affected by a cut-back of loan supply. This finding is consistent with the notion that information available about the firm and

collateral improve access to external funds. Fifth, firms partly mitigate the contraction in loan supply by resorting to internal financing, by increasing nominal capital, and by establishing new bank relationships. As far as we know, we provide the first evidence on firms' adjustment responses in the field. Our results are robust to specification choices.

Our first contribution to the literature is to document the effects of the financial crisis of 2007/8 on the real economy.³ Data limitations have made it difficult to show that shocks to financial markets transmit to the real economy.⁴ In particular, micro data for many countries are only released with long time lags and usually either contain bank-level information on credit supply or borrower-level information on real outcomes. A notable exception is the data used by Chodorow-Reich (2014), who jointly observes financial information of banks and employment outcomes at firms, and who finds contractions in employment by firms that had pre-crisis banking relationships with less healthy lenders.⁵

For lack of similar data on firms' bank relationships and capital stock, previous studies on the effects of the financial crisis of 2007/8 on investment have resorted to variation in firms' financial liquidity. In particular, they exploited ex-ante variation in firms' long-term debt maturity (Almeida et al. 2012) and variation in firms' internal financial resources (Duchin et al. 2010). Both studies find corporate investment in the US to significantly decline

³ This strand of research builds on earlier papers interested in how financial shocks to banks affect their borrowers. For instance, Gan (1997) and Amiti and Weinstein (2011) exploit the bursting of the Japanese real estate bubble, Ongena et al. (2003) the Norwegian bank crisis, Schnabl (2012) the 1998 Russian default, and Khwaja and Mian (2008) unanticipated nuclear tests in Pakistan affecting bank liquidity. Ashcraft (2005) shows bank failures of healthy banks to lead to a significant and permanent decline in real county income within Texas, but cannot study the effect at the firm level.

⁴ There are several papers relating credit supply and market evaluation of borrowers. For instance, Slovin et al. (1993) and Baur (2012) find that financial crises lead to an increased co-movement of returns between financial sector stocks and the stocks of their borrowers, thereby providing indirect evidence that financial crises affect the real economy. A survey among CFOs in the U.S., Europe, and Asia suggests that firms forewent profitable investment opportunities during the crisis as a result of binding external financial constraints (Campello et al. 2010) while Claessens et al. (2012) do not find the financial crisis 2007/8 to affect investment of firms in advanced and emerging economies. Bricongne et al. (2012) examine the effect on international trade and find the overall impact of the financial crisis to be limited.

⁵ Amiti and Weinstein (2013) exploit a large sample of matched bank-firm loan data for Japan for the period 1990 to 2010. They trace loan movements back to bank, firm, industry, and common shocks, and find that bank supply shocks explain about 40 percent of aggregate loan and investment fluctuations. As noted by Chodorow-Reich (2014), loan data and loan application data has the limitation that firms expecting not to obtain credit are discouraged from applying for credit and are thus missing in the data.

following the onset of the financial crisis of 2007/8. Our paper differs from these earlier studies on the investment effects of the financial crisis in three important dimensions: First, we exploit a data base which contains both bank-related and firm-related information. We can therefore compare investment behavior of firms that had borrowed before the crisis from relatively healthy banks with that of otherwise similar firms that had borrowed from banks which were more adversely affected by the financial crisis. Second, we also observe small and medium-sized firms, listed or unlisted. Previous investment studies focused on large, public firms, which may find it easier to compensate for a bank credit contraction by issuing bonds or stocks. Third, we document the US financial crisis to have caused real effects also outside the US economy. The shock was transmitted by banks in Germany which tightened credit supply towards corporate customers in Germany after they had incurred losses on the US financial market.⁶

As a second contribution we add to the literature on the effects of the globalization of banking for the international transmission of financial shocks (Peek and Rosengren 1997, Chava and Purnanandam 2011). Relatively little research has been done on how financial crises in other countries transmit internationally to the corporate sector and the real economy (Peek and Rosengren 2000). Our study advances this literature by showing how a large shock to the US financial markets affected real activity in Germany as a major European economy.

Our third contribution to the literature consists in presenting evidence on the effects of the financial crisis of 2007/8 on corporate lending.⁷ While it has been previously documented that banks sharply curtailed lending to the corporate sector during the past financial crisis (e.g., Ivashina/Scharfstein 2010 for the US and Popov/Udell 2012 for Europe), we show the

⁶ Puri et al. (2011) examine the cross-border effects of the US financial crisis of 2007/8 on retail bank lending in Germany. They show that saving banks which were indirectly affected by the US financial crisis through their holdings in Federal State Banks (*Landesbanken*) with substantial sub-prime exposure rejected substantially more loan applications than non-affected banks.

⁷ The financial crisis also renewed interest on the effects of monetary policy on banks' credit supply and credit risk-taking, see e.g., Jimenez et al. (2012, 2014).

importance of relationship lending in this transmission. Firms cannot fully offset a contraction in credit supply by their relationship banks by switching to other banks.

Finally, our paper contributes to the strand of the literature which examines the cash flow sensitivity of capital-constrained and capital-unconstrained firms (cf. Fazzari et al. 1988, Hoshi et al. 1991, Dell’Ariccia et al. 2008). We shed light on this question from a different angle by focusing on whether investment decisions are determined by loan supply shocks, and by providing evidence on adjustment channels.

This paper is organized as follows. Section 2 describes relevant features of the banking system in Germany. Section 3 introduces our data and section 4 the empirical methodology used. Section 5 presents our empirical results both on firm borrowing and firms’ real investment. In that section we also analyze heterogeneity in responses and firms’ potential adjustment channels. Section 6 concludes. The appendix contains additional data description and further empirical findings.

2 German banks, the U.S. financial crisis, and lending

There are three features of the German financial system which are central to our study: First, the German financial system is bank based rather than capital-market based, and relationship lending is important. Second, the German banking system was hit hard by the U.S. financial crisis as several German banks had significant direct exposure to toxic assets. Third, banking regulation puts limits on credit supply to bank customers based on bank balance sheet indicators. In the following, we will describe each of these three institutional features in greater detail.

2.1 Predominant role of bank financing and relationship lending

In Germany, domestic banking sector assets exceeded 300% of GDP prior to the financial crisis (compared to about 70% in the United States), which shows the major importance of

banks for the German economy. On the other hand, financial markets have traditionally been less important for financing businesses: The ratio of stock market capitalization to GDP was only about a third (45%) of the one observed in the U.S. (130%) prior to the crisis.⁸ The predominant role of bank financing is also reflected in firms' balance sheets: Bank loans account for 60% of total long-term corporate debt in Germany⁹ (U.S.: 20% only) and represent the lion's share of newly borrowed capital, while the issuance of corporate bonds plays a minor role (share of bonds issued in newly borrowed capital of 10%¹⁰ compared to 50% in the U.S.).

These differences in financing can partly be explained by the importance of small and medium-sized enterprises in Germany (the German *Mittelstand*). Access to financial markets for these firms is more limited due to their smaller size (Petersen and Rajan 1994, Harhoff and Körting 1998). Usual information asymmetries are aggravated between small and medium-sized firms and investors as these firms are i. less likely to be monitored by rating agencies, ii. younger (providing less of a track record), and iii. subject to weaker disclosure requirements. All of these factors increase the importance of sticky bank-borrower relationships as a way to mitigate information asymmetries (Diamond 1991, Hoshi et al. 1991; see Petersen and Rajan 1994 for an overview of the theoretical foundations). If bank-borrower relationships matter for the lending process, borrowers cannot easily switch banks when their relationship bank becomes liquidity constraint (Slovin et al. 1993). Sticky bank-borrower relationships thus make firms more vulnerable to shocks to the banking sector.

In summary, the German financial system is dominated by banks. Banks are the main providers of external finance to firms that traditionally have maintained stable, long-term

⁸ Deutsche Börse, 2003.

⁹ Deutsche Bundesbank (2011), Extrapolated results from financial statements of German enterprises 1997 to 2009, Table I.

¹⁰ Deutsche Börse, 2001.

business relationships with one (or several) relationship bank(s) (*Hausbank*). Relationship banking makes German firms particularly vulnerable to shocks to the banking system.

2.2 German banks severely hit by the U.S. financial crisis

Germany has universal banking where banks are active both as commercial banks and as investment banks (in addition to providing insurance and other financial services). Universal banks account for 97% of all institutions and 75% of assets (Hüfner 2010). The combination of different banking activities under one roof make lending activities of German banks particularly susceptible to liquidity shocks from investment activities.

The German banking system is highly fragmented and the majority of bank institutions are not strictly profit-maximizing. There are three kinds of banks: private banks, cooperative banks, and public sector banks. Public sector banks include saving banks (owned by municipalities)¹¹ and *Landesbanken* (owned by the regional savings banks and by the federal state in which it is located). Saving banks also offer universal services but are limited in their regional activity to the municipality in which they are located (“regional principle”). Their legal mandate is not to maximize profits but to provide financial services to their region and to strengthen competition in the banking sector. *Landesbanken* act as central institution for the regional saving banks (e.g., financing infrastructure projects) and as main bank for the federal state in which they are located. Together, public banks accounted for about 40% of total assets prior to the crisis,¹² which was significantly more than in any other OECD country.

The importance of the aforementioned roles as public institution, however, has tapered off and *Landesbanken* have increasingly operated as commercial banks on an international scale (Puri et al. 2011). These business operations have been backed up by the public founding entities which guaranteed that the bank can meet its financial obligations at all times

¹¹ Six (out of 431) saving banks are not owned by municipalities, these are: Bordesolmer Sparkasse AG, Die Sparkasse Bremen AG, Hamburger Sparkasse AG, Sparkasse zu Lübeck AG, Sparkasse Mittelholstein AG and Sparkasse Westholstein.

¹² Worldbank Financial Regulation Database, values for 2005.

(by providing liquidity support and capital injections if needed). Among several *Landesbanken* the guarantees have caused excessive risk taking and large exposure to international financial risks.

Even though the German economy grew until early 2008, German banks were severely hit from the outset of the U.S. financial crisis as they had heavily invested in structured credit products in the U.S.. Columns (2) and (3) in Table 2 show the investment of selected German banks in toxic conduit- and special investment vehicles financed assets prior to the crisis. In total, the investment of German banks in toxic assets was estimated to equal 230 bn. Euro (Hüfner 2010). These investments led to significant write-downs of several billions of Euro in 2007 and 2008, see column (4) of Table 2. According to Bloomberg 7% of global write-down on such assets between 2007 and 2009 can be attributed to German banks. In 2010, German banks' portfolios still contained substantial amounts of structured products (total of more than 200 billion of Euro, Deutsche Bundesbank 2010) requiring further write-downs.

Table 1: Exposure of selected German banks to U.S. structured credit products

	Ownership	Conduit- and special investment vehicles financed assets prior to the crisis		Asset write- downs 2007/08
	(1)	... in % of capital (2)	... in % of assets (3)	... in bn. US\$ (4)
Sachsen LB	Public (<i>Landesbank</i>)	1 126	30.3	2.5
WestLB	Public (<i>Landesbank</i>)	542	12.7	4.6
IKB Deutsche Industriebank AG	Private	494	20.5	14.8
Dresdner Bank AG	Private	364	9.9	3.9
Landesbank Berlin	Public (<i>Landesbank</i>)	179	2.2	Unknown
Bayern LB	Public (<i>Landesbank</i>)	170	5.1	6.9
HSH Nordbank	Public (<i>Landesbank</i>)	126	4	3.5
Deutsche Bank AG	Private	114	3.3	10.4
HypoVereinsbank AG	Private	105	6.6	unknown
Nord LB	Public (<i>Landesbank</i>)	89	2.9	unknown
Commerzbank AG	Private	85	2.2	2.3
Helaba	Public (<i>Landesbank</i>)	68	1.1	unknown
DZ-Bank AG	Private (Co-operative)	61	1.3	2.6
LB Baden-Württemberg	Public (<i>Landesbank</i>)	59	1.7	4.7
KfW	Public	58	2.6	unknown

Notes: Comparability is limited by different dates and varying definitions.

Source: Hüfner (2010), Table 1 (which is based on Fitch Ratings (2007), ABCP Concerns Trigger Liquidity Issues for German Banks, Germany Special Report, August) and Onaran/ Pierson, Bloomberg, September 29, 2008.

The write-downs in the course of the U.S. financial crisis significantly burdened the result of banks' own trading activities and caused massive problems to several German banks. The U.S. financial crisis thus directly affected banks' financial scope for supplying credit to customers. Furthermore, several private banks and *Landesbanken* needed to be rescued by interventions of their owners in order to prevent default. Since the affected *Landesbanken* are partly owned by saving banks, which had to make guarantees or equity injections, the write-downs in the wake of the crisis also indirectly narrowed the financial scope for some of the saving banks.

2.3 Banking regulation sets limits to money creation and credit supply

The Eurosystem and banking regulation set certain limits on bank money creation and credit supply by banks. First, the European Central Bank (ECB) requires credit institutions to hold compulsory deposits on accounts with the national central banks. In the period of this analysis, this minimum reserve requirement was 2% of the sight deposits that non-banks hold at a bank.¹³ Thus, banks cannot lend out more than 50 times the amount they hold as central bank money. To obtain central bank money in central bank credit operations, banks have to provide collateral. During the financial crisis, the ECB extended the range of assets it accepted as collateral several times in order to sustain liquidity in the financial market (European Central Bank 2013).

Second, banking regulation requires a bank to hold a certain amount of equity capital for every credit risk or other risk it takes. According to the rules of the Basel I Accord, which were in place till the end of 2006, credit lent out to business customers had to be backed by 8% equity capital. Since 2007, according to the refined rules of the Basel II Accord, the 8% equity capital requirement is weighted by the default risk of the credit, i.e., the credit-

¹³ The minimum reserve requirement was reduced to 1% in January 2012.

worthiness of the customer.¹⁴ The overall Tier 1 capital ratio must not fall below 4%. The regulations imply that banks suffering losses may not be able to provide further credit if their equity falls below the capital adequacy requirement. Even if the equity is still above the threshold, losses may induce banks to restrict lending because the smaller equity buffer implies a larger risk of falling below the threshold in the future. In case of universal banks active in both, proprietary trading and commercial banking, large losses from proprietary trading may thus spill over to a reduction of their commercial lending activity through the impact on the common equity base.

3 Individual firm and bank panel data

3.1 Linking bank and firm data via individual bank relationships

The database of the empirical analysis are financial statements of German non-financial firms linked with the financial statements of each firms' relationship banks. Both data sources are provided by Bureau van Dijk. The financial statements database Dafne of non-financial firms includes information for the years 2004 to 2010 and beginning in 2006 it covers more than 85% of all incorporated firms in Germany, listed and unlisted.¹⁵ Since small firms do not have to publish their income statements, sales and profit information are only available for a subsample.¹⁶ Besides the balance sheet and income statements, the database includes further information on the ownership structure of the firms, the location of the headquarters, and the

¹⁴ Subsequently, the financial crisis led to the development of stricter regulations. According to the "Basel 2.5" rules of 2009, certain securities have to be backed by more equity capital than before. Since 2014, after the period of this analysis, the Basel III Accord requires banks to provide generally more equity capital, and also introduces new liquidity standards. For details on the Basel regulations, see, e.g., Blundell-Wignall and Atkinson (2010).

¹⁵ The financial statements of incorporated firms can be collected by Bureau van Dyke because of the strict publication requirements.

¹⁶ According to Art. 267 of the German Commercial Code, small firms fulfill at least two of the following three conditions: 1) Total assets are equal or less than 4 015 million euro; 2) Sales are equal or less than 8 030 million euro; and/or 3) the number of employees is equal to or less than 50.

bank(s) a firm reports as its relationship bank(s). We observe the names and bank identification codes of the relationship banks, but not the amount borrowed from them. All these information are updated regularly, usually at of the end of the financial year.

Using the identification codes of the relationship banks, we merge unconsolidated financial statements for each relationship bank to each single firm. The bank financial statements stem from the Bankscope database of banks active in Germany for the years 2004 to 2010. It includes balance sheets and income statements as well as information on ownership, affiliated companies, and branches. A comparison with the German Bank Statistics provided by the German Central Bank shows that Bankscope covers on average 83% of all banks in Germany over this time period.

Our estimation sample uses data from 2005-2010, which is reduced to 2006-2010 by taking first differences (see section 4.1). Lagged control variables in first differences additionally use the year 2004. From the over four million firm-year observations included in the firm database before taking first differences, we drop the smallest firms with total assets worth less than ten thousand euro (US\$ 6 960 on 1/1/2010), and firms in the real estate industry as these firms might be directly affected by the subprime market crisis in the U.S.. For 1 760 130 of the 1 839 904 firm-year observations left after this first selection process, we have information on the firms' relationship banks, at least from 2007 onwards. For 97% of these firm-year observations (1 714 434), we are able to match bank statements for all relationship banks. Since we require firms to be observed in 2006 and to have at least two repeated observations, the number of observations is reduced to 507 457 firm-year observations. Our last selection step concerns the availability of information on long-term lending by all relationship banks of a firm, which leaves us with 291 079 firm-year observations in the final sample. From the 1 700 banks on average in Bankscope per year, around 90% have a lending relationship to at least one firm covered in our final sample. Since

we also require information on long-term lending of banks, the rate of inclusion in our sample is reduced to 80%.

3.2 Firm and bank characteristics and time trends

Table 2 shows descriptive statistics for the firms in our sample. The average firm has a balance sheet total (=total assets) of 10.9 million euro, fixed assets of 2.2 million euro, and liabilities of 4.8 million euro.¹⁷ The growth rates of fixed assets and liabilities are on average 1.1% and 0.6% and exhibit substantial variation between and within firms. Based on the number of firms for which sale information are available, the average turnover amounts to 20 million euro with an average annual growth of 1.8%.

¹⁷ For both fixed assets and liabilities, we exclude the bottom and top 1% from the sample to avoid that outliers drive the estimated coefficients.

Table 2: Descriptive statistics of the firms

	Mean	Std dev.	25% quantile	Median	75% quantile	Observations
Total assets in thd. euro	10 876	368 147	254	604	1 789	291 079
Fixed assets in thd. euro	2 183	69 317	27	72	278	291 079
Growth rate in fixed assets	0.011	0.431	-0.223	-0.054	0.152	291 079
Liabilities in thd. euro	4 797	155 648	101	280	896	291 079
Growth rate liabilities	0.006	0.498	-0.209	-0.007	0.214	291 079
Debt ratio	0.540	0.299	0.281	0.543	0.805	291 079
Sales in thd. euro	28 370	502 955	700	1800	6000	88 153
Growth rate sales	0.018	0.305	-0.010	0.000	0.070	88 153
Nominal capital in thd. euro	720	24 258	26	26	52	291 079
Growth rate nominal capital	0.002	0.170	0	0	0	288 414
Cash in thd. euro	691	26 720	9	51	206	286 087
Growth rate cash	0.034	1.239	-0.499	0.015	0.561	258 798
Age of the firm	17	14	9	14	20	291 079
Ratio tangible assets over total assets	0.291	0.234	0.103	0.222	0.428	291 079
Increase amount of corporate bonds	0.005	0.073	0.000	0.000	0.000	48 709
Number of banking partners	1.404	0.684	1	1	2	291 079
Savings bank as partner	0.481					291 079
Local cooperative bank as partner	0.195					291 079
Other bank as partner	0.570					291 079
Thereof: Large private bank as partner	0.332					291 079
Savings bank in distress as partner	0.149					291 079
Avg. growth rate credit supply banking partners	0.024	0.163	0.000	0.000	0.000	290 704
Avg. growth rate long-term credit supply banks	0.010	0.220	0.000	0.000	0.000	290 704
One or more additional bank(s)	0.017					158 760
One or more bank(s) less	0.017					158 760
Change in number of banking partners	-0.002	0.224	0	0	0	158 760
Change of banking partners (constant no.)	0.030					158 760
Business tax rate	0.322	0.046	0.28	0.31	0.37	291 079
Change in business tax rate	-0.021	-0.007	0.000	0.000	0.038	291 079

Notes: The main sample includes 291 079 firm-year observations for 2006-2010 without missing values in the variables used in the main estimations. Some additional variables reported here are not available for all firms and years in this sample, which leads to a smaller number of firm-year observations reported in the rightmost column. For dummy variables, only the mean and the number of observations are reported.

Source: Authors' calculations based on the firm financial accounts database Dafne, 2006-2010; growth rates also use 2005.

The firms in our sample have on average 1.4 relationship banks. Almost half of the firms have at least on savings bank as a banking partner, 20% a local cooperative bank, and 33% one of the large private banks. 1.7% of the firms establish an additional business relationship to a bank in a given year, and about the same percentage terminate an existing banking partnership, such that the average change in the number of relationship banks is close to zero. For 3% of the firms, a relationship bank is swapped for another within a year, keeping the number of relationship banks constant. Overall these descriptive statistics suggest that firm-bank relationships are very stable over time, presumably because establishing a banking

relationship is costly for firms, as it involves developing a reputation for non-opportunistic behavior in order to counteract informational asymmetries (Harhoff and Körting 1998).

The average tax rate firms face amounts to 32% in the pooled sample. It includes the corporate income tax rate, the mandatory so-called solidarity surcharge, as well as the local business tax rate. The rates of the latter depend on the location of the firm and differ across the more than 12 000 municipalities in Germany and over time. They range from a minimum tax rate of 9% to about 20% with an average rate of about 16% (Fossen and Bach 2008).¹⁸ The combined business tax rate has substantial time series variation due to the corporate tax reform 2008, which reduced the corporate income tax rate from 25% to 15%, and also included changes in the local business tax.¹⁹

The descriptive statistics for the banking partners of the firms included in our sample are reported in Table 3. Germany's the three pillar system is reflected in the data, in that from all banking partners 28% are saving banks, 29% local cooperative banks and the rest are other private banks. Due to a few very large private banks, the average of total assets is 5.8 billion euro, whereas the median is only 488 million euro. The average annual growth rate of credit and long term credit is 2.6% and 1.8%, respectively. The mean gains from proprietary trading activities are 165 thousand euro. Only a quarter of the banks engage in proprietary trading; conditional on nonzero gains or losses from these activities, the mean gains are 659 thousand euro.

¹⁸ We matched the local business tax rates provided by the Federal Statistical Office using the postal codes of the firms.

¹⁹ Further changes due to the corporate tax reform concern the generosity of depreciation allowances and special anti-avoidance provisions as the tightened thin capitalization rule (see e.g. Buslei and Simmler 2012).

Table 3: Descriptive statistics of the banking partners

	Mean	Std dev.	25% quantile	Median	75% quantile	Observations
Total assets in thd. euro	5 817 691	55 932 584	197 300	488 650	1 274 600	6 640
Credit supply in thd. euro	2 287 862	16 005 645	104 400	267 250	705 950	6 640
Ratio credit supply / total assets	0.567	0.144	0.491	0.582	0.658	6 640
Credit supply, growth rate	0.026	0.080	-0.009	0.018	0.048	6 623
Long term credit supply in thd. euro	979 880	4 746 310	59 300	154 500	412 100	6 640
Ratio long term credit supply / total assets	0.339	0.109	0.283	0.350	0.410	6 640
Long term credit supply, growth rate	0.018	0.099	-0.024	0.010	0.050	5 529
Gains from proprietary trading in thd. euro	165	149 350	0	0	0	6 640
Nonzero gains from proprietary trading	659	298 498	100	100	400	1 663
Financial assets (w/o credit) in thd. euro	1 438 360	13 002 858	17 100	78 450	249 050	6 640
Ratio other earning assets / total assets	0.386	0.144	0.293	0.371	0.464	6 640
Ratio deposits / total assets	0.876	0.081	0.863	0.895	0.916	6 640
Tier 1 capital ratio	0.105	0.030	0.084	0.099	0.121	482
Ratio equity / total assets	0.066	0.032	0.052	0.061	0.074	6 640
Savings bank	0.280					6 640
Local cooperative bank	0.292					6 640
Other bank	0.428					6 640

Notes: The main sample includes 6 640 bank-year observations of banks that were indicated as a relationship bank by at least one firm in the firm sample and without missing values in the variables used in the main estimations. Some additional variables reported here are not available for all banks and years in this sample, which leads to a smaller number of bank-year observations reported in the rightmost column. For dummy variables, only the mean and the number of observations are reported.

Source: Authors' calculations based on the bank financial accounts database Bankscope, 2006-2010; growth rates also use 2005.

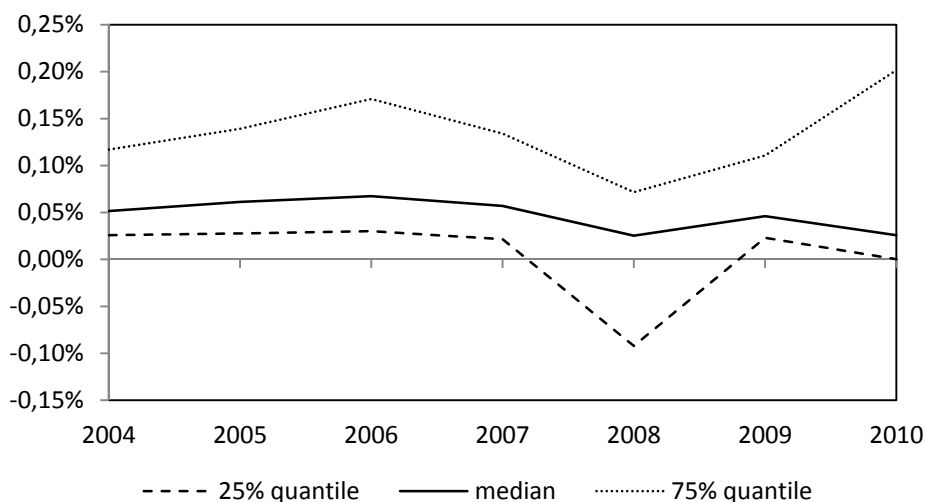
Do certain types of firms select into banking relationships with certain types of banks?

Table A 1 in the Appendix reports mean characteristics of the firm in the sample by the type of their relationship banks. Larger firms seem to be more likely to have at least one relationship bank that engages in proprietary trading. This is often one of the major private banks in Germany.²⁰ Smaller firms are more likely to have local cooperative banks or savings banks as their banking partners, many of which do not engage in proprietary trading. Apart from size, firms with the different types of banking partners seem to be quite similar, for example, in terms of their industry distribution. In Table A 2, we look at the characteristics of the banks by bank type. It is obvious that the major private banks are fundamentally larger than the other banks. This also increases the average size of the trading banks in comparison to the non-trading banks. Local cooperative banks are the smallest banks on average.

²⁰ Commerzbank, Deutsche Bank, Dresdner Bank, HypoVereinsbank/UniCredit, and Postbank; Dresdner Bank merged into Commerzbank in 2009.

We depict the evolution of banks' gains and losses from proprietary trading activities for all nonzero observations in Figure 1, scaled by financial assets (which do not include credit provided by the banks). There is a clear dip in 2008, which is even more pronounced at the first and third quartiles of the distribution than at the median. This reflects the impact of the financial crisis on banks in Germany.

Figure 1: Distribution of gains and losses from proprietary trading of banks over time



Notes: Quartiles of non-zero gains and losses from proprietary trading activities of the banks in the sample, normalized by the bank's financial assets.

Source: Authors' calculations based on the bank financial accounts database Bankscope, 2004-2010.

The idea behind this paper is that banks that suffer losses from proprietary trading activities will reduce their lending, as their equity shrinks and official bank regulation and a bank's internal risk management demand that every loan be backed by a certain amount of equity. If capital markets are imperfect and relationship banking is important, firms that have relationship banks that reduce lending will find it harder to raise capital and will therefore tend to reduce their real investment. This bank lending and firm borrowing channel may be responsible for the transmission from a financial crisis to a crisis of the real economy.

Before our econometric analysis, in this section, we inspect time trends to see if our data reflect these patterns. Figure A 1 in the Appendix splits the bank observations into those of banks that engage in proprietary trading activities, as identified by non-zero gains or losses

from proprietary trading in 2005 and 2006, and those that do not. The time trends (indexed at 2006=1) are very similar for both groups of banks between 2004 and 2006, but with the financial crisis starting in 2007, the credit amount lent out by trading banks falls behind notably. These banks are likely to be directly hit by the financial crisis, which originated in the U.S., through their proprietary trading with sub-prime mortgage and other securities in the U.S.. In contrast, any effects of the crisis on credit demand should affect both groups of banks in the same way, which strongly suggests that the difference is due to the proprietary trading losses. The difference between the two groups of banks is even more pronounced when looking at the growth of long-term credit with a term of at least five years (Figure A 2 in the Appendix). A comparison with Figure 1 in this section shows that the pronounced dip in long-term credit supply by trading banks in 2008 accompanies the dip in gains from proprietary trading in the same year. This suggests that banks that suffer losses from proprietary trading reduce their credit supply relative to other banks.

What are the consequences for real investment? Figure A 3 in the Appendix depicts the growth of fixed assets of the firms in our sample. We distinguish between firms that have business relationships exclusively with banks that do or do not engage in proprietary trading activities, or a mixture of both, in 2005 and 2006. Before 2008, the time trends look similar. In 2009, firms that exclusively have trading banking partners have a slower growth of fixed assets than firms with exclusively non-trading banking partners, although the difference is not very large. This may suggest that real investment is impaired by lending relationships with banks in financial distress. The small relative slow-down of investment in comparison to the larger relative decline in credit supply may also indicate that firms can raise at least part of the desired capital in alternative ways when their relationship banks reduce lending. An econometric analysis is necessary to identify causal effects and possible adjustment channels.

4 Empirical methodology

4.1 The effect of credit supply by relationship banks on real investment

Our goal is to estimate how much firms reduce real investment as a result of a contraction of credit supply by their relationship banks. In a world with perfect capital markets, firms would make any profitable investment, i.e., an investment yielding a higher expected and possibly risk-adjusted return than the world capital market return. The investment decision would thus be independent from specific financing sources such as relationship banks, because funds could always be obtained at the interest rate demanded by the world capital market. Therefore, if we find evidence for a causal effect of credit supply by relationship banks on firm investment, this would provide evidence for imperfect capital markets and more specifically, for liquidity constraints impacting real investment.

To assess the effect of the bank lending and firm borrowing channel on real investment, we consider the following model:

$$\log(K_{it}) = \beta_0 + \beta_1 \log(\text{credit supply}_{it}) + \beta_2 \log(\text{credit supply}_{i,t-1}) + \beta_3 t + \mathbf{\beta}'_4 \mathbf{x}_{it} + \mathbf{\beta}'_5 \mathbf{w}_i + \mathbf{\beta}'_6 t \mathbf{w}_i + \delta_i + \theta_t + \varepsilon_{it}, \quad (1)$$

where i indicates firms and t years ($t=0$ for the first year of observation), and bold letters indicate vectors. K_{it} is the book value of the firm's stock of fixed assets. The information is obtained from a firm's balance sheet. We define the variable $\text{credit supply}_{it}$ as the book value of the credit volume that a firm's relationship banks grant to their customers (excluding credits to other banks). These data are taken from the balance sheets of the banking partners of a firm. The credit supply can be interpreted as a measure of bank health, cf. Chodorow-Reich (2014). We also include the first time lag of $\text{credit supply}_{it}$ in the model to account for possible dynamic effects.

The coefficients β_1 and β_2 are coefficients of primary interest. If they are consistently estimated as the causal effects of credit supply, they represent the elasticities of a firm's

capital stock with respect to the capital supply by its relationship banks. If the elasticities are zero, the model implies that a firm's real investment is not affected by a change in the credit supplied by their relationship banks. This is what we would expect in case of perfect capital markets, where investments should not depend on the lending behavior of certain banks. The variables $credit\ supply_{it}$ and its time lag are endogenous, and we apply an instrumental variable approach to consistently estimate the coefficients, as explained in the following subsection.

The model eq. (1) includes unobserved firm fixed effects δ_i . To avoid bias due to unobserved firm heterogeneity, we eliminate the firm fixed effects by taking first differences. First-differencing also removes all time-invariant terms in eq. (1). Using the common log approximation of a relative change, $\log(K_{it}) - \log(K_{i,t-1}) \approx \frac{\Delta K_{it}}{K_{i,t-1}}$, the equation in first differences is written as

$$\frac{\Delta K_{it}}{K_{i,t-1}} = \beta_1 \frac{\Delta credit\ supply_{it}}{credit\ supply_{i,t-1}} + \beta_2 \frac{\Delta credit\ supply_{i,t-1}}{credit\ supply_{i,t-2}} + \beta_3 + \beta'_4 \Delta x_{it} + \beta'_6 w_i + \Delta \theta_t + \Delta \varepsilon_{it}. \quad (2)$$

The dependent variable is the one-year growth rate in K_{it} , i.e., real net investment relative to the stock of fixed assets. The key explanatory variables are the current and lagged one-year growth rates in the credit volume of the firm's relationship banks lend to their customers. If a firm has more than one relationship banks, we take the average of their growth rates.

The vector of time varying control variables x_{it} includes the tax rate on business profits, and its first time lag to account for possibly dynamic effects of taxation on investment. As mentioned in section 3.1, there is substantial time-series and regional variation in the tax rate, which makes it a potentially important control variable. Furthermore, x_{it} in some specifications includes a firm's total value of sales as a measure of firm size. For the majority of firms, we only observe balance sheet information; we additionally observe income statements for less than a third of the sample. As sales are reported in the income statement, we only include sales in additional robustness checks based on a sub-sample of firms.

Time-invariant control variables are collected in the vector w_i , including the shares of savings banks that became financially distressed during the crisis and of banks with US affiliates in a firm's set of banking partners in 2006. We control for linear time trends that may differ by the values of these time-invariant firm characteristics by including interactions of t and w_i . Furthermore, we account for time effects θ_t that are common to all firms to pick up business cycle effects.

4.2 Endogeneity and instrumental variables approach

We treat the variables $credit\ supply_{it}$ and its time lag as endogenous and apply a Two-Stages Least Squares (2SLS) instrumental variable (IV) approach, because even after eliminating the unobserved firm-specific effect, these variables are endogenous for four reasons.

First, we are interested in the causal effect of credit supply on real investment by firms, but we measure the credit volume of the bank, which is determined by supply and demand. During the crisis, investment opportunities are reduced, and therefore credit demand. We expect a positive correlation between a firm's capital stock and the credit volume of their relationship banks even in case of perfect capital markets, because firms investing are likely to demand more credit from their relationship banks first, even if they could obtain the funds from other sources as well. This would lead to a positive coefficient in an OLS regression even if there was no causal effect of credit supply on the capital stock. To isolate the supply effect from the demand effect, we require supply shifters as instrumental variables, which are correlated with the bank's credit supply, but independent from credit demand.

Second, we do not observe the growth rates of the loans a bank grants to a specific firm, but only the growth rate of the bank's total credit volume. This can be seen as the growth of the loans to a specific firm with a measurement error. The IV method econometrically accounts for measurement error.

Third, we intend to identify the bank lending channel, i.e., the causal transmission from bank distress to reduced firm borrowing and investment, isolated from the firm balance sheet channel. The latter channel describes reduced credit flow due to problems in the balance sheets of the non-financial business customers, which occur when their real estate or financial assets, and thus the collateral firms can provide, are devaluated. Prior literature has found it difficult to separate the channels, because problems in the balance sheets of the banks and of their customers often occur simultaneously in an economic downturn. We thus require instruments that are related to the bank's health and independent of the balance sheets of the firms.

Forth, firms may change their relationship banks because they do not obtain the desired credit from their initial banking partners. This endogenously changes the explanatory variable of interest, the credit supply of the current relationship banks. Therefore, we require instruments that are independent of changes in the firm-specific set of banking partners.

Our first excluded instrument is the gains and losses from proprietary trading activities of the banks that the firm had a banking relationship with in 2006, normalized by financial assets (which do not include credit). We consider the average value of all banking partners if a firm has more than one banking partner. We expect the two identification assumptions to hold. First, the IV likely explains a bank's lending behavior: Banks that suffer losses from proprietary trading experience a decline in their equity. Since banking regulation forces banks to back loans by a certain percentage of equity (see Section 2.3), large losses from trading may put a limit to further lending. Even if minimum equity requirements are still met, moving closer to the threshold is likely to make banks more reluctant to lend because of the smaller buffer for future risks. We empirically explore the relationship between proprietary trading gains and lending, i.e., the strength of the IV, in first stage regression.

Second, the assumption that a bank's gains and losses from proprietary trading activities are exogenous and can be excluded from the investment equation of the firm is highly

plausible. Gains and losses from proprietary trading activities are independent of their customers' business by definition: Proprietary trading activities are defined as the financial trading activities which a bank conducts on its own account with the aim to generate profits, and which are unrelated to business with their customers. Initial selection of firms into bank relationships based on a bank's proprietary trading activities is also very unlikely. Trading gains and losses cannot be anticipated by a bank, let alone by their business customers, who only have very limited insight into the proprietary trading activities of their banking partners. Especially in the context of the financial crisis, banks in Germany experienced large losses from trading due to investments in subprime mortgage and other securities in the USA and other foreign countries. The risk involved in these trading activities was unexpected, and firms did not pay attention to these activities of their banking partners before the outburst of the crisis. Moreover, proprietary trading losses of German banks in the U.S. financial market are not subject to unobserved shocks that simultaneously hit the German business customers of a specific bank in comparison to shocks other firms in Germany also experience during the crisis. Also, there is no reason to expect a bank's gains and losses from trading activities to directly influence firms' investment decisions—we only expect an indirect effect of gains and losses from trading through the bank lending and firm borrowing channel that we are explicitly modelling. Thus, proprietary trading gains of banks are exogenous from the viewpoint of individual firms, as required for the IV approach.

As a second excluded instrument, we adopt the idea of Puri et al. (2011) and exploit that certain savings banks were affected by the financial crisis while other savings banks were not. The affected savings banks have substantial holdings in certain Federal State Banks (*Landesbanken*), which had large exposure to the U.S. subprime market and were deeply hit by the financial crisis.²¹ As discussed in Section 2.2, the affected savings banks had to make

²¹ The affected Federal State Banks are: Bayern LB, Sachsen LB (acquired by Landesbank Baden-Württemberg in 2008), and West LB (Puri et al., 2011).

guarantees or equity injections into the distressed Federal State Banks, which is likely to have reduced their willingness and ability to lend to business customers. Following Puri et al. (2011), we identify these savings banks by their location in the same Federal State as the affected Federal State Banks. We compute the share of these affected savings banks in a firm's set of banking partners in the first year of observation, 2006. Even though we fix this variable in the initial year, the initial choice of such banking partners might already be non-random, so we include this time-invariant characteristic in the vector of time-invariant controls w_i .²² The excluded IV is an interaction of this characteristic with a dummy variable indicating the time period starting in 2007, when we expect the financial crisis to have affected the savings banks (cf. Puri et al. 2011). Thus, identification in the IV approach only exploits the changed lending behavior of the affected savings banks during the crisis.²³ This second IV adds information to the first IV, because the exposure of the savings banks to the financial crisis through their holdings in Federal States Banks does not appear in the gains and losses from their proprietary trading.

The availability of two excluded instrumental variables for one endogenous explanatory variable allows us to test statistically whether the other IV is valid under the assumption that one IV is valid (over-identification test). The test is passed in all specifications, which increases confidence in the exogeneity of the excluded instruments.

Another candidate for an excluded IV is the share of banks with affiliated banks (and companies) in the U.S. in a firm's set of banking partners, as the financial crisis originated in the U.S.. As before, we consider the choice of such banks to be potentially non-random and include the share of banks with affiliates in the U.S. in w_i in the regressions that use the additional IV. The IV is an interaction of this share with a year dummy for 2008, the climax

²² Since eq. (1) accounts for differential linear time trends by the characteristics in w_i , we control for w_i in the first and second stage of the first-differenced IV regression, see eq. (2).

²³ In alternative specifications, we interact a firm's share of savings banks in 2006 affected by the financial crisis with a time dummy for the year 2008 only, when the affected savings banks were most strongly hit by the crisis.

of the banking crisis in the U.S.; Lehman Brothers collapsed in fall 2008. Unfortunately, our bank data only provides information on affiliates for 2012; we assume a bank's structure of affiliates in earlier years to correspond to the one observed in 2012, which implies some measurement error. Because of this data limitation, we use this third IV in additional robustness checks only. The over-identification test is passed even with the set of three instruments.

The isolation of the bank lending channel from the firm balance sheet channel by our IV approach would fail if firms invested in similar financial assets as their relationship banks in their proprietary trading activities, because then shocks to the assets of the firms would be correlated with their banks' trading losses. However, this is very unlikely. As shown in section 3.2, firms with different types of relationship banks may differ in average size, but not markedly in other characteristics such as their industry composition.

To account for the endogeneity introduced by the possibility of firms to change their relationship banks, we fix the firm-specific set of relationship banks as observed in 2006 (the first year of observation in our sample) for all subsequent years when we construct any of the three instrumental variables discussed above.²⁴ Thus, changes in the set of banking partners do not affect the IV.

4.3 The effect of bank lending on firm borrowing

Before we assess how the credit supply by relationship banks affects investment of firms, we first estimate how it affects firm borrowing. The estimation of the borrowing equation gives initial insights into the importance of relationship lending. If bank relationships are unimportant, which would be the case under perfect capital markets, a firm will choose an optimal debt level and will always be able to find banks willing to lend the amount desired, independently of the lending behavior of the specific banking partners. To test this, we

²⁴ If the information on the relationship banks is missing for a firm in 2006, we use the information from 2007 instead.

estimate a first differenced equation with the right hand side as in eq. (2), but with the growth rate of the liabilities L in a firm's balance sheet as the dependent variable (instead of the growth rate of fixed assets):

$$\frac{\Delta L_{it}}{L_{i,t-1}} = \gamma_1 \frac{\Delta \text{credit supply}_{it}}{\text{credit supply}_{i,t-1}} + \gamma_2 \frac{\Delta \text{credit supply}_{i,t-1}}{\text{credit supply}_{i,t-2}} + \gamma_3 + \gamma'_4 \Delta x_{it} + \gamma'_6 w_i + \Delta \vartheta_t + \Delta \epsilon_{it}. \quad (3)$$

If lending relationship are unimportant, we expect the elasticities of the firms' liabilities with respect to the current and lagged credit supply of their relationship banks, γ_1 and γ_2 , to be zero, if consistently estimated. Coefficients larger than zero imply that the ability to borrow partly depends on the credit supply by a firm's relationship banks. Again, we are interested in the causal effect of credit supply, and the measured growth rate in the credit volume of the banking partners may be endogenous for the same reason in the firm borrowing equation as discussed before in the context of the investment equation. Therefore, we apply the same IV approach.

5 Empirical results

5.1 Bank lending and firm borrowing

Elasticity of firm liabilities. Table 2 reports the results when we estimate the firm borrowing eq. (3) with the growth rate in a firm's liabilities as the dependent variable. In the first column, the coefficient γ_1 of the credit supply by a firm's relationship banks is positive, but small and insignificant, whereas the coefficient of the first time lag γ_2 is much larger and significant at the one percent level. This indicates that the credit supply of relationship banks indeed propagates to the liabilities of their business customers but with a time lag, which may be due to the time lag between the date of negotiation and agreement about a bank loan and the date when the loan is actually paid out. While the bank loan appears in a bank's balance sheet immediately after agreement (loan commitment), it only shows up in the firm's balance sheet once the loan is paid out. Because we empirically detect this lag structure in column (1),

in the following regressions, we omit the insignificant contemporaneous growth rate of credit supply and concentrate on γ_2 . In column (2), the elasticity of the firm's liabilities with respect to the credit supply of its banking partners is 0.109 and significant at the one percent level. Thus, if a firm's relationship banks contract credit supply by one percent, this causes the firm's liabilities to decrease by about 0.1 percent. This is the isolated effect of credit supply by the banking partners, because the IV approach removes any demand effect from the coefficient estimate. The positive and significant effect shows that relationship banking is important in Germany. Firm borrowing is affected by the lending policy of their relationship banks, which indicates that firms cannot fully substitute credit from their relationship banks by credit from other banks. In column (3), we include lagged sales (in first differences) as an additional control variable. As sales are observed only in the sub-sample of firms that report income statements, the sample size drops significantly in this estimation ($N = 88\,153$ instead of $N = 291\,079$). The estimated elasticity remains almost unchanged.

In summary, the results on bank lending and firm borrowing imply that firm-bank lending relationships are an important determinant of firms' access to external capital. Our results contribute to a nascent literature on the role of relationship banking for the transmission of monetary shocks (Hachem 2011, Bolton et al. 2013) and to the small empirical literature examining relationship banking (for the U.S. cf. Petersen and Rajan 1994, for Germany cf. Harhoff and Körting 1998).

Table 4: Credit Supply by Relationship Banks Affects Firm Liabilities

2SLS regressions of firms' liability growth rates on credit supply growth rates of their banking partners

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Credit supply, growth rate (i)	0.029 (0.031)								
L.Credit supply, growth rate (ii)	0.141*** (0.040)	0.109*** (0.035)	0.106** (0.048)				0.106*** (0.035)	0.084*** (0.023)	
Long-term credit supply, growth rate (i)				0.069 (0.114)					
L.Long-term credit sup., growth rate (ii)				0.389*** (0.103)	0.322*** (0.105)	0.303** (0.143)			0.265*** (0.075)
D.Business tax rate	0.222 (0.248)	0.202 (0.247)	0.746* (0.449)	0.243 (0.255)	0.206 (0.247)	0.726 (0.450)	0.203 (0.247)	0.224 (0.247)	0.237 (0.247)
L.D.Business tax rate	-0.048 (0.279)	-0.045 (0.278)	0.076 (0.398)	0.080 (0.284)	0.049 (0.285)	0.190 (0.411)	-0.049 (0.278)	-0.050 (0.277)	0.049 (0.283)
L.D.Sales			0.136*** (0.008)			0.137*** (0.008)			
Share of savings banks in distress	0.002 (0.003)	0.002 (0.003)	-0.002 (0.005)	0.002 (0.003)	0.002 (0.003)	-0.001 (0.005)	0.002 (0.003)	0.001 (0.003)	-0.000 (0.003)
Share of banks with US affiliates								-0.015* (0.008)	-0.023** (0.009)
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Constant	0.011*** (0.003)	0.013*** (0.003)	0.018*** (0.004)	0.015*** (0.003)	0.016*** (0.003)	0.020*** (0.004)	0.013*** (0.003)	0.016*** (0.002)	0.018*** (0.002)
Number of observations	291 079	291 079	88 153	291 079	291 079	88 153	291 079	291 079	291 079
Shea's Partial R ² for (i)	0.08			0.01					
1 st stage F-statistic for (i)	107.14			171.77					
Partial Shea's R ² for (ii)	0.06	0.07	0.08	0.01	0.01	0.02	0.07	0.16	0.02
1 st stage F-statistic for (ii)	233.68	333.81	376.00	309.04	185.53	277.48	1 299.98	6 500.67	1 367.76
Hansen test: p-value	0.40	0.89	0.22	0.51	0.62	0.17	0.20	0.96	0.67
Excluded instruments	IV set 1	IV set 2	IV set 2	IV set 2	IV set 2	IV set 2	IV set 3	IV set 4	IV set 4

Notes: Estimations at the firm level. The dependent variable is the firm-specific growth rate in liabilities. The growth rates are log approximations. The growth rate of (long-term) credit supply, the share of savings banks in distress, and the share of banks with US affiliates pertain to the firm's relationship bank(s). We link firms to their banking partners via information on individual firm-bank relationships. If a firm has multiple relationship banks, we calculate the means of the (long-term) growth rates of their credit supply. D. indicates the first time difference of a variable and L. lagged values. Standard errors are robust to heterogeneity and clustering at the firm level. ***/**/* indicate significance at the 1%/5%/10%-level. The (long-term) growth rate of credit supply and its first time lag (L.) are treated as endogenous. In the different specifications we use alternative sets of excluded instruments:

IV set 1: Proprietary trading gains and the share of savings banks in distress during the crisis among a firm's 2006 set of relationship banks in 2007 onwards. Contemporaneous and lagged variables.

IV set 2: As IV set 1, but with lagged variables only.

IV set 3: As IV set 2, but with a dummy variable indicating savings bank in distress during the crisis among a firm's 2006 set of relationship banks in 2008 (instead of 2007 onwards).

IV set 4: As IV set 2, but with the share of banks with US affiliates among a firm's 2006 set of relationship banks in 2008 as additional excluded IV.

Source: Authors' calculations based on the firm financial accounts database Dafne and the bank financial accounts database Bankscope, 2006-2010; (lagged) first differences also use 2005 (2004).

First stage results. Before we explore further specifications, we inspect the first stage results from the 2SLS estimation. They are displayed in Table A 3 in the Appendix. In the first (second) column, the dependent variable is the (long-term) credit supplied by the relationship banks of a firm to their customers. As expected, we find a positive correlation between successful proprietary trading activities and the growth rate of loans provided: Banks with higher gains from proprietary trading activities (normalized by their financial assets, excluding credit) increase the volume of credits approved, while banks which incur losses from trading activities due to the financial crisis reduce their lending volume. Since losses in proprietary trading were mostly due to write-downs of asset-backed securities in the US financial market, the result indicates that the financial crisis in the US affected loan supply in Germany, which documents the transmission of the crisis from one country to another. The variable “share of savings banks in distress” indicates the share of savings banks in the 2006 set of a firm’s relationship banks that came into distress during in the financial crisis, as explained in Section 4.2. The interaction of this variable with the dummy variable indicating the period of financial crisis, in and after 2007, has a negative and significant coefficient. This is consistent with reduced lending by those savings banks in Germany, which were affected by the US financial crisis through their holdings of distressed Federal State Banks, after the onset of the financial crisis. The two rightmost columns of Table A 3 show the first stage results when the share of banks with US affiliates in the 2006 set of a firm’s relationship banks, interacted with 2008, is used as an additional excluded instrument in the 2SLS estimations. The estimates are consistent with reduced credit supply by banks with US affiliates during the climax of the financial crisis.

The first stage statistics, which are shown at the bottom of Table 4, indicate that our instrumental variables are strong. The F -statistic of a test of exclusion of the two instruments from the first stage estimation is well above 100 in all specifications. In column (1) of Table 4, the first stage F -statistic may not be sufficient to show the strength of the instruments

because there are more than one endogenous explanatory variables in this specification (contemporaneous and lagged growth rate of credit supply), so we additionally inspect Shea's Partial R^2 here, which is sufficiently large. Since we have more excluded instruments than endogenous variables in all specifications, we can apply Hansen's over-identification test. The null hypothesis can be rejected in all estimations, as indicated by the p -values reported in Table 4. This shows that under the assumption of exogeneity of one excluded IV, the other excluded instruments are found to be exogenous.

Long-term credit supply. Let us now turn back to the second stage results in Table 4 and study long-term bank loans. Long-term bank loans are defined as loans with a term of at least five years. Again we first estimate a model with the contemporaneous and lagged growth rate in long-term credit supply. Column (4) shows that the coefficient of the contemporaneous variable is insignificant and much smaller than that of the lagged variable, as before, and we omit the contemporaneous variable in the subsequent regressions. The estimated elasticity of firm liabilities with respect to the amount of long-term credit supply by relationship banks is 0.322 in column (5) and significant at the one percent level. The point estimate is almost thrice the size of the estimate we obtain for the total of credit supply in column (2). This shows that firm borrowing is much more sensitive to the amount of long-term credit supplied by banking partners. As real investment by firms mostly relies on long-term loans, these results already suggest that investment may react sensitively to credit supply by relationship banks. We assess this directly in the following subsection.²⁵

Effect size. To shed further light on the size of the economic effect, we roughly estimate the effect size of losses from proprietary trading during the financial crisis on firm borrowing. The mean losses from proprietary trading of the banks in our sample between 2007 and 2008,

²⁵ In a robustness check, we use the growth rate in firms' bank liabilities instead of firms' total liabilities as the dependent variable. Within our sample, this more detailed information is available for 27 876 observations only. After removing outliers (10% of this subsample), the point estimate of the elasticity of bank liabilities is 0.109 and thus identical to the baseline point estimate in column (2), but it comes with a fairly large standard error and turns insignificant due to the small sample size.

normalized by financial assets, is -1.21 percentage points (from 0.069% down to -1.137%). Inserting this in the first stage equation for long-term credit supply (Table A 3 in the Appendix), we obtain $-0.0121 * 0.832 = -0.01$. Thus, the financial crisis decreased the mean growth rate of long-term credit supply by one percentage point, i.e., more than half of the mean growth rate in the sample of 1.8% (cf. Table 3). We insert this in the second stage equation in column (5) of Table 4 and obtain $-0.01 * 0.322 = -0.0032$. Thus, the financial crisis causally decreased the growth rate in firm liabilities through losses from proprietary trading of the firm's relationship banks by 0.32 percentage points, which is 54% of the mean net real investment rate of 0.6% in the sample (cf. Table 3). We obtain a very similar relative effect size of 55% when we repeat these calculations using all credit supply instead of long-term credit supply. The cut-back of firm borrowing by more than half on average indicates that the effect of distressed relationship banks on firm borrowing during the crisis was economically very important.

Robustness checks. Before we leave the firm borrowing equation, we show that the results are robust to the instrumental variables used. In column (7) of Table 4, we vary our definition of the period of crisis. Instead of interacting the share of savings banks in distress in a firm's 2006 set of relationship banks with a dummy for year 2007 onwards (baseline estimations), we define the period of crisis as the year 2008 only. The rationale behind is that the financial crisis most severely hit in 2008 (see discussion in Section 4.2). The estimated elasticity of firm liabilities remains almost unchanged in comparison to column (2). Next, we explore the share of banks with U.S. affiliates in the firm's 2006 set of banking partners, interacted with 2008, as another excluded IV.²⁶ The point estimate of the elasticity in column

²⁶ Here, we use the share of banks with US affiliates in the 2006 set of a firm's relationship banks as additional control variable in both stages of the 2SLS estimations. When we use this control variable in our main specifications with only two instruments, the point estimate of the elasticity of interest is not significantly different from the estimate in column (2) and remains significant at the one percent level. We do not use this control variable in the main estimations because our bank data only provides information on affiliated banks for 2012 and we have to assume that a bank with (without) a U.S. affiliate in 2012 also had an (had no) U.S. affiliate in earlier years, which introduces some measurement error (see discussion in Section 4.2).

(8) declines somewhat, but is not statistically different from the baseline estimate in column (2). In column (9), we again use all three instruments, but focus on long-term debt (instead of total debt). Again the point estimate of the elasticity of debt turns out smaller, but not statistically different from the estimate using two instruments (column (5)). Both in columns (8) and (9), adding the third excluded instrument increases the strength of the instruments. Hansen's over-identification test is still passed. Lastly, the results are very similar to the baseline results in column (2) when gains from proprietary trading are used as the only excluded instrument (not shown in the table). Overall, we conclude that the results are robust with respect to the choice of instruments.²⁷

5.2 Real investment effects

Elasticity of firm fixed assets. After having established that borrowing by firms reacts to changes in the credit supply by their relationship banks, we next focus on firms' investment decisions. Table 5 presents our results from estimating eq. (2). Given the results from the previous section, we again use the lagged growth rate of credit supplied by the banking partners as the main explanatory variable. The estimated elasticity of a firm's stock of fixed assets with respect to the credit supplied by its banking partners is 0.073 and significant at the one percent level. In column (2), we additionally control for sales (in first differences) as a measure of firm size, based on the sub-sample of firms for which income statements (and thus sales) are observed. The point estimate of the elasticity of the stock of fixed assets increases slightly and remains significant at the 5%-level.

²⁷ In another robustness check, we additionally include the lagged growth rate of total assets (as a measure of the change in firm size) and the lagged first difference in the ratio of fixed assets over total assets (as a measure of the change in tangibility or collateral) in the first differenced equation. The point estimate and standard error of the elasticity of interest remain virtually unchanged compared to our main specification in column (2). We do not include these controls in the main estimations because of potential endogeneity concerns (which would be even more pronounced when we turn to investment).

Table 5: Credit Supply by Relationship Banks Determines Firms' Real Investment

2SLS regressions of firms' fixed assets growth rates on credit supply growth rates of their banking partners

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
L.Credit supply, growth rate	0.073*** (0.027)	0.077** (0.038)			0.079*** (0.027)	0.052*** (0.019)	
L.Long-term credit supply, growth rate			0.211*** (0.081)	0.221** (0.112)			0.149** (0.059)
D.Business tax rate	-0.371* (0.217)	-0.640* (0.377)	-0.368* (0.217)	-0.654* (0.378)	-0.371* (0.217)	-0.339 (0.218)	-0.332 (0.218)
L.D.Business tax rate	-0.586** (0.239)	-0.777** (0.343)	-0.527** (0.245)	-0.694** (0.353)	-0.578** (0.239)	-0.571** (0.238)	-0.523** (0.243)
L.D.Sales		0.116*** (0.006)		0.116*** (0.006)			
Share of savings banks in distress	0.005* (0.003)	0.011** (0.005)	0.004* (0.003)	0.012*** (0.005)	0.005* (0.003)	0.003 (0.003)	0.002 (0.003)
Share of banks with US affiliates						-0.023*** (0.007)	-0.027*** (0.007)
Year dummies	yes	yes	yes	yes	yes	yes	yes
Constant	-0.000 (0.003)	0.009** (0.004)	0.002 (0.002)	0.011*** (0.003)	-0.001 (0.003)	0.003 (0.002)	0.005*** (0.002)
Number of observations	291 079	88 153	291 079	88 153	291 079	291 079	291 079
Shea's Partial R ²	0.07	0.08	0.01	0.02	0.07	0.16	0.02
1 st stage F-statistic	333.81	376.00	185.53	277.48	1 299.98	6 500.67	1 367.76
Hansen test: p-value	0.60	0.34	0.43	0.27	0.15	0.79	0.31
Excluded instruments	IV set 2	IV set 2	IV set 2	IV set 2	IV set 3	IV set 4	IV set 4

Notes: Estimations at the firm-level. The dependent variable is the firm-specific growth rate in fixed assets. The growth rates are log approximations. The growth rate of (long-term) credit supply, the share of savings banks in distress, and the share of banks with US affiliates pertain to the firm's relationship bank(s). We link firms to their banking partners via information on individual firm-bank relationships. If a firm has multiple relationship banks, we calculate the mean of the (long-term) growth rates of their credit supply. D. indicates the first time difference of a variable and L. lagged values. Standard errors are robust to heterogeneity and clustering at the firm level. ***/**/* indicate significance at the 1%/5%/10%-level. The (long-term) growth rate of credit supply is treated as endogenous. In the different specifications we use alternative sets of excluded instruments:

IV set 2: Lagged trading gains and lagged share of savings banks in distress during the crisis among a firm's 2006 set of relationship banks in 2007 onwards.

IV set 3: As IV set 2, but with a dummy variable indicating savings bank in distress during the crisis among a firm's 2006 set of relationship banks in 2008 (instead of 2007 onwards).

IV set 4: As IV set 2, but with the share of banks with US affiliates among a firm's 2006 set of relationship banks in 2008 as additional excluded IV.

Source: Authors' calculations based on the firm financial accounts database Dafne and the bank financial accounts database Bankscope, 2006-2010; (lagged) first differences also use 2005 (2004).

These results show that monetary shocks to the banking sector indeed transmit to the real economy. Since firm investment depends in part on the willingness of relationship banks to lend, our results indicate imperfect financial markets. Apparently, firms cannot fully offset reduced credit supply by their relationship banks by resorting to other sources of finance, such that they reduce real investment. Again, the IV approach ensures that we estimate the causal effect of credit supply by a firm's banking partners, isolated from potential credit demand effects. Thus, if a bank reduces its credit supply because it suffers losses from proprietary

trading activities, its business customers will have to decrease their real investment. Our estimation identifies the bank lending and firm borrowing channel as a causal transition mechanism between a financial crisis and a crisis of the real economy.

First-stage results. The instruments are strong, as indicated by the large F -statistics for tests of joint significance of the excluded instruments in the first-stage regression, which are reported at the bottom of the table. Hansen's over-identification test is passed in all specifications, which suggests our instruments to be valid. Note that we use the same set of instruments and explanatory variables as in the previous section, so that the first stage regression is unchanged (see Table A 3 in the Appendix).

Long-term credit supply. When we use long-term credit supply by the banking partners instead of all credit supply, we obtain much larger estimates for the elasticity of a firm's stock of fixed assets, in line with our finding for a firm's liabilities. The elasticity is 0.211 without (0.221 with) controlling for sales, and significant at the 1% (5%) level; see columns (3) and (4). This confirms that firm investment is much more sensitive to long-term credit supply by relationship banks than to their general credit supply, which is also what we expect as real investment mostly relies on long-term funds.

Effect size. We roughly estimate the effect of bank losses from proprietary trading during the crisis on the net real investment rate of non-financial firms. In the previous sub-section, we used the first-stage results to calculate that the growth rate of long-term credit supply shrank by 1 percentage point due to these losses. We insert this in the second stage equation in column (3) of Table 5 and obtain $-0.01 * 0.211 = -0.0021$. This indicates that proprietary trading losses of relationship banks caused a decrease in the net real investment rate of their business clients by 0.21 percentage points through the bank lending and firm borrowing channel. This is 19% of the mean net real investment rate in the sample of 1.1% (cf. Table 2). We obtain a very similar estimate of 20% when we use all credit supply instead of long-term

credit supply in the calculation. Thus, the economic effect of the financial crisis on real investment through distressed relationship banks is economically significant.

Robustness checks. As in the previous subsection, we assess the sensitivity of the results with respect to the set of instrumental variables used. In column (5), we again vary our definition of the period of crisis. For the interaction term of the share of savings banks in the firm's 2006 set of banking partners which were in distress during the crisis period, we define the crisis period as year 2008 only (instead of the period 2007 onwards). The point estimate and significance of the elasticity of the capital stock remains very similar to the baseline estimate in column (1). Next, we add the share of banks with U.S. affiliates in the 2006 set of a firm's relationship banks, interacted with a dummy indicating year 2008, as a third excluded IV.²⁸ In column (6), using all credit supply, the point estimate of the elasticity of interest decreases, but remains significant at the one percent level; the point estimate is statistically indistinguishable from the estimate obtained in our main specification, column (1). This also holds true when we focus on long term credit supply by the banking partners in column (7): The point estimate is smaller, but not statistically different from the point estimate in our main specification for long term credit in column (3), and it remains statistically significant. The results also remain similar to the baseline in column (1) when gains from proprietary trading are used as the only instrument. We conclude that our results prove to be robust to the choice of instruments.

In the main estimations, as the key explanatory variable we use the average growth rate of credit supply in case a firm has more than one banking partners. One might argue that as long as one of the relationship banks is healthy and does not contract lending, the firm should not be affected by the problems of the other banking partners. Therefore, in an additional robustness check, we use the maximum of the growth rates of credit supply from all banking

²⁸ Here, we additionally control for the share of banks with U.S. affiliates in the 2006 set of a firm's relationship banks in both stages of the 2SLS regression.

partners instead, i.e., we consider a firm's best bank only. The results in Table A 4 show that the point estimates of the effect sizes of the credit supply growth rate increase somewhat, both on the growth rates of the liabilities and the fixed assets of the firms. The differences to the main estimates are not statistically significant, so we conclude that the results are robust.

Furthermore, one might be concerned that some firms may not only have a lending relationship with their banking partners, but that these banks at the same time own shares of the firms' equity. In this case, the effects of bank distress on firm borrowing and investment may not only work through the bank lending and firm borrowing channel, but a bank may influence a firm's behavior directly through its ownership share. In two additional robustness checks, we therefore exclude all firms from the sample that have i.) banks as owners, or ii.) any financial institutions, private equity or venture capital firms as their owners. The results with respect to firm liabilities and investment remain very similar to the baseline results, so ownership does not confound the effects we measure. Last not least, subsidiaries of foreign banks or real estate banks may be affected by the financial crisis through their foreign parent organizations or their real estate customers. Therefore, in two additional robustness checks, we exclude firms with one of the two groups of banks as banking partners from the estimation sample, and again obtain very similar results.

5.3 Effect heterogeneity

In this section, we explore whether investment by certain groups of firms reacts more or less sensitive to changes in credit supply by their relationship banks. Our large and comprehensive micro data base includes many small and medium sized firms; while mean total assets are €10 876 thousand, the first quartile is only €254 thousand and the median €604 thousand (cf. Table 2). This allows us to assess heterogeneous effects by firm size. We expect smaller firms to react more strongly, because they may have limited access to the financial market and to alternative sources of financing such as issuance of additional equity or bonds, e.g., due to

fixed transaction costs.²⁹ To assess possible heterogeneous effects empirically, we split the sample at the median of total assets and estimate eq. (2) separately, using the same IV method as before. Columns (1) and (2) of Table 6 show that the point estimate of the elasticity of the stock of fixed assets with respect to the banking partners' credit supply is larger for smaller firms and smaller for larger firms. This is consistent with the expectations, although the difference is not statistically significant. A related dimension is firm age. Younger firms may be affected more by informational asymmetries and may therefore depend on relationship banks more strongly. We split the sample at the median age of the companies, which is 14 years. Indeed, the point estimate of the elasticity in columns (3) and (4) is larger for younger firms than for older firms, but the difference again is not statistically significant.

²⁹ All the firms in our sample are incorporated with limited liability.

Table 6: Heterogeneous Effects by Firm Types

2SLS regressions of firms' fixed assets growth rates on loan growth rates of their banks

	Firm size		Firm age		Capital intensity		Tangibility	
	Below median	Above median	Below median	Above median	Below median	Above median	Below median	Above median
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.Credit supply, growth rate	0.092** (0.046)	0.067** (0.033)	0.079* (0.041)	0.067* (0.036)	0.077** (0.038)	0.069* (0.038)	0.120*** (0.039)	0.038 (0.038)
D.Business tax rate	-0.467 (0.326)	-0.271 (0.287)	-0.250 (0.322)	-0.536* (0.291)	-0.622** (0.315)	-0.180 (0.298)	-0.536 (0.337)	-0.526* (0.278)
L.D.Business tax rate	-0.280 (0.366)	-0.854*** (0.310)	-0.681* (0.355)	-0.509 (0.321)	-0.778** (0.362)	-0.443 (0.318)	-0.729* (0.386)	-0.557* (0.291)
Share of savings banks in distress	0.002 (0.004)	0.012*** (0.004)	0.001 (0.004)	0.008** (0.003)	0.010** (0.004)	0.001 (0.003)	0.007* (0.004)	0.000 (0.003)
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes
Constant	-0.001 (0.004)	-0.000 (0.003)	0.002 (0.004)	-0.003 (0.003)	-0.006 (0.004)	0.004 (0.003)	0.014*** (0.004)	-0.015*** (0.003)
Number of observ.	144 554	146 525	137 879	153 200	122 590	168 489	145 537	145 542
Shea's Partial R ²	0.06	0.08	0.06	0.07	0.07	0.07	0.08	0.06
1 st stage F-statistic	135.83	423.74	125.06	392.61	105.60	390.51	416.27	128.67
Hansen test: p-val.	0.80	0.92	0.25	0.68	0.76	0.66	0.75	0.77
Excluded IV	IV set 2	IV set 2	IV set 2	IV set 2	IV set 2	IV set 2	IV set 2	IV set 2

Notes: Estimations at the firm-level. The dependent variable is the firm-specific growth rate in fixed assets. The growth rates are log approximations. The growth rate of (long-term) credit supply, the share of savings banks in distress, and the share of banks with US affiliates pertain to the firm's relationship bank(s). We link firms to their banking partners via information on individual firm-bank relationships. If a firm has multiple relationship banks, we calculate the mean of the bank variables for each firm-year observation. D. indicates the first time difference of a variable and L. lagged values. Standard errors are robust to heterogeneity and clustering at the firm level. ***/**/* indicate significance at the 1%/5%/10%-level. The growth rate of credit supply is treated as endogenous. In the different specifications we use alternative sets of excluded instruments:

IV set 2: Lagged trading gains and lagged share of savings banks in distress during the crisis among a firm's 2006 set of relationship banks in 2007 onwards.

Source: Authors' calculations based on the firm financial accounts database Dafne and the bank financial accounts database Bankscope, 2006-2010; (lagged) first differences also use 2005 (2004).

Next we explore heterogeneous effects by capital intensity, defined as the ratio of total book assets over sales. We take averages of this ratio by detailed industry classes (second most detailed digit in the classification scheme used by the statistical offices) because for many individual firms, we do not observe sales, as mentioned above. We split the sample at the median. The point estimates for the elasticity we obtain from the separate estimations are similar and not significantly different from one another. So far, the analysis of heterogeneous effects demonstrates that the estimated elasticity is fairly robust to the choice of subgroups of firms.

Finally, we split the sample by the ratio of fixed assets over total assets, which is an indicator of tangibility. Firms with a higher share of tangible assets can provide more

collateral and may find it easier to obtain loans from banks they do not yet have a lending relationship with. Therefore, we expect investment of firms with higher tangibility to be less sensitive to changes in credit supply by their existing relationship banks. The estimated elasticities in columns (7) and (8) confirm this, as the elasticity is large and significant at the 1%-level for firms with tangibility below the median, but small and insignificant for those above the median. We thus find more support for heterogeneous effects with respect to tangibility than to the other dimensions.

5.4 Adjustment channels

In the previous sections, we provided evidence that both, borrowing and investment by firms, react significantly to credit supplied by their relationship banks. Which alternative ways of financing do firms have when their banking partners contract lending? In this section, we explore possible adjustment channels by estimating 2SLS regressions in first differences similar to equation (2), but using different dependent variables. In column (1) of Table 7, we use the growth rate of cash, which is held within the firm or in the form of liquid bank deposits. We find a significant elasticity of cash with respect to the credit supply by the relationship banks of 0.162, which indicates that cash reserves shrink when a firm faces a decreasing credit supply by its banking partners. This suggests that firms use up their internal cash reserves when facing credit constraints, which is consistent with internal self-financing.³⁰ Column (2) of Table 7 shows that firms significantly increase their nominal capital when credit supply by relationship banks is shortened. External self-financing is thus another way firms use to alleviate a shortage of credit supply from their relationship banks.³¹

³⁰ The point estimate even increases to 0.254 (std dev.: 0.122) for firms that did not pay out dividends in or before 2007 and that have only one relationship bank that does not change. These firms run down their cash reserves quickly when credit supply from their only relationship bank dries out, because they cannot retain any more earnings, and they cannot find a substitute for their banking partner.

³¹ The estimated effect is even -0.035 (std dev.: 0.017) for firms that did not pay out dividends in or before 2007, and with tangibility (fixed assets/total assets) below the median. This result is consistent with the view that these firms cannot find a new bank willing to lend to them because they lack collateral, and issuing new equity is the only way of financing available to these firms.

Table 7: Adjustment Channels of Firms

2SLS regressions

Dependent variable	Cash, growth rate	Nominal capital, growth rate	Change of banking partners		Change in number of banking partners	
	(1)	(2)	(3)	(4)	(5)	(6)
Credit supply, growth rate			-0.024* (0.015)		-0.040*** (0.016)	
L.Credit supply, growth rate	0.162* (0.093)	-0.019* (0.011)				
D.Business tax rate	-0.225 (0.644)	0.103 (0.084)	-0.363*** (0.103)	-0.404*** (0.102)	-0.330*** (0.126)	-0.289** (0.125)
L.D.Business tax rate	-2.041*** (0.738)	0.017 (0.109)	-0.282*** (0.109)	-0.390*** (0.105)	0.190 (0.133)	0.110 (0.129)
Share of banking partners with proprietary trading losses				0.003*** (0.001)		0.004*** (0.001)
Number of banking partners in 2006			0.016*** (0.001)	0.016*** (0.001)	-0.044*** (0.002)	-0.044*** (0.002)
Share of savings banks in distress	0.001 (0.008)	-0.002*** (0.001)	-0.010*** (0.001)		0.004*** (0.001)	
Year dummies	yes	yes	yes	yes	yes	yes
Constant	0.035*** (0.009)	-0.015*** (0.001)	0.021*** (0.002)	0.020*** (0.002)	0.046*** (0.002)	0.047*** (0.002)
Number of observations	258 798	288 414	158 760	158 760	158 760	158 760
Shea's Partial R^2	0.07	0.07	0.04	0.95	0.04	0.95
1 st stage F -statistic	296.71	329.47	37.93	1.33e+06	37.93	1.33e+06
Hansen test: p -value	0.56	0.32	0.59		0.72	
Excluded instruments	IV set 2	IV set 2	IV set 2	IV set 5	IV set 2	IV set 5

Notes: Estimations at the firm-level. The growth rate of (long-term) credit supply, the share of savings banks in distress, and the share of banks with US affiliates pertain to the firm's relationship bank(s). We link firms to their banking partners via information on individual firm-bank relationships. If a firm has multiple relationship banks, we calculate the mean of the bank variables for each firm-year observation. D. indicates the first time difference of a variable and L. lagged values. Standard errors are robust to heterogeneity and clustering at the firm level. ***/**/* indicate significance at the 1%/5%/10%-level. The number of observations is smaller in these estimations than in the main estimations because the dependent variables are not available for all firm-year observations (cf. Table 2). The increase in nominal capital includes strong outliers, so we remove 1% of the sample in column (2). The growth rate of credit supply and its first time lag (L.) and the share of banking partners with proprietary trading losses are treated as endogenous. In the different specifications we use alternative sets of excluded instruments:

IV set 2: Lagged trading gains and lagged share of savings banks in distress during the crisis among a firm's 2006 set of relationship banks in 2007 onwards.

IV set 5: Share of banking partners in a firm's 2006 set of relationship banks that experience proprietary trading losses in the year of observation.

Source: Authors' calculations based on the firm financial accounts database Dafne and the bank financial accounts database Bankscope, 2006-2010; (lagged) first differences also use 2005 (2004).

Another adjustment channel may be the change of banking partners or the establishment of additional bank relationships when the prior relationship banks contract lending. In column (3), we use a dummy variable as the dependent variable, which is one if a change in the set of banking partners occurs while the number of banking partners remains constant, and zero otherwise. Here, as the key explanatory variable, we use the contemporaneous growth rate in the credit supply of the relationship banks instead of the first time lag, because a new banking

relationship is already established at the time of the credit negotiations. We additionally control for the number of banking partners in 2006, the first year of observation. The results indicate that the probability of switching a banking partner significantly increases when credit supply by the prior relationship banks decreases. Similarly, column (5) shows that the number of banking partners significantly grows when loan supply by the prior partners decreases.

We take a different approach in columns (4) and (6). Instead of the growth rate of credit supply by the relationship banks, we use the share of banks with losses from proprietary trading in a firm's current set of banking partners as the explanatory variable of main interest. This variable may be seen as an indicator of exposure of a firm to the financial crisis through its relationship banks. As the current share of relationship banks with trading losses is endogenous to changes of relationship banks, we treat it as endogenous in a 2SLS estimation. The excluded IV is the share of banking partners with trading losses in 2006. We find that a higher current share of banking partners with trading losses significantly increases the probability of a change of banking partners and also increases the number of banking partners of a firm. Thus, the results from columns (3)-(6) consistently suggest that some firms whose relationship banks are in financial distress are able to change banking partners or find additional ones, which mitigates the effect of the financial crisis on the real economy in Germany.

6 Conclusion

To investigate the effect of bank distress on borrowing and real investment of non-financial firms, we merge financial statements of individual firms and their relationship banks in Germany for 2004-2010. The large and comprehensive data include small and medium-sized firms. Our analysis exploits exogenous variation in the individual exposure of banks in Germany to the US financial crisis in 2007/08.

We find that reduced credit supply by banks in Germany that were hit by the US financial crisis was a significant channel in the international transmission of the crisis. Firms in Germany with lending relationships with distressed banks that contract credit supply reduce overall borrowing, which indicates that the firms cannot fully substitute loans from their banking partners by loans from other banks. Furthermore, these firms reduce real investment, which indicates that other sources of financing cannot fully offset the reduction in credit supply by their relationship banks either. Overall, the mean net real investment rate of non-financial firms in Germany was reduced by a fifth in 2008 because of losses from proprietary trading that their relationship banks suffered during the financial crisis.

We document that smaller and younger firms tend to be dependent more on their relationship banks. This is consistent with the view that asymmetric information is responsible for the importance of relationship lending. Furthermore, firms that provide more collateral are less affected by a reduction in credit supply by their banking partners, since they can borrow from other banks more easily. We show that firms can partially offset a contraction in credit supply by their relationship banks by resorting to self-financing or by establishing new banking relationships.

Overall, our results imply that capital markets are imperfect, and that real investment is coupled to financial markets through the bank lending and firm borrowing channel. Thus, globalization of banking increases the danger of transmission of a financial crisis in one country to real economic crises in other countries.

A possible implication for banking regulation is that a separation of investment banking from commercial banking could reduce the contagion risk from a financial to a real economic crisis. The transmission channel analyzed here would be disrupted: Losses from proprietary trading would not reduce the common equity base of a universal bank anymore and would not impede the ability of commercial banks to lend to non-financial firms. These considerations give support to banking separation initiatives such as the Volcker rule in the USA and the

Liikanen-report in the EU. The flip side of this coin is that universal banking may facilitate diversification of risks in other economic situations.

For the economic modelling and policy management of crisis, our results document the importance of the bank lending and firm borrowing channel in the development of a real economic crisis. Distress on the side of banks causally spills over to real investment of non-financial firms. This implies that monetary and fiscal policy should aim at maintaining credit supply during a crisis.

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Appendix Tables

Table A 1: Firm Characteristics by Type of Banking Partners

	Firms with...					
	Trading vs. non trading banks			Type of banking partner		
	Non-trading banks only	Trading & non-trading banks	Trading banks only	Savings banks	Local cooperative banks	Other banks
Total assets in thd. euro	3 912	18 769	11 863	4 387	2 515	17 700
Capital stock in thd. euro	867	4 163	2 220	1 459	719	3 296
Growth rate capital stock	0.010	0.023	0.007	0.015	0.018	0.012
Total liabilities in thd. euro	1 797	7 664	5 387	1 948	1 146	7 728
Debt ratio	0.547	0.538	0.537	0.55	0.56	0.53
Growth rate liabilities	0.002	0.007	0.008	0.007	0.007	0.006
Number of banking partners	1.136	2.335	1.249	1.56	1.68	1.60
Savings bank	0.290	0.630	0.528	1.000	0.339	0.259
Local cooperative bank	0.327	0.395	0.069	0.138	1.000	0.085
Other bank	0.489	0.783	0.545	0.308	0.248	1.000
Industries:						
Agriculture, forestry	0.019	0.008	0.008	0.009	0.016	0.124
Mining and quarrying	0.001	0.001	0.001	0.001	0.001	0.034
Manufacturing	0.181	0.254	0.180	0.199	0.208	0.406
Energy- and water supply	0.006	0.009	0.006	0.007	0.005	0.070
Construction	0.181	0.175	0.127	0.178	0.213	0.410
Wholesale and retail trade	0.230	0.252	0.222	0.231	0.252	0.434
Hotels and restaurants	0.027	0.013	0.032	0.027	0.022	0.145
Transport, storage and communic.	0.054	0.047	0.051	0.050	0.050	0.218
Financial intermediation	0.013	0.011	0.015	0.010	0.009	0.096
Renting and business activities	0.208	0.176	0.264	0.200	0.164	0.371
Public administration and defense	0.012	0.007	0.013	0.011	0.008	0.088
Education	0.024	0.016	0.027	0.028	0.015	0.122
Health and social work	0.046	0.031	0.054	0.049	0.037	0.188
Firm-year observations	79 373	49 784	161 922	139 933	56 787	165 934

Notes: The table shows mean firm characteristics by categories of the banking partners the firms have. In the calculation of the means by the type of banking partner, all firms with at least one banking partner of the respective type are used. Therefore, and because statistics for the category “other type of banking partner” are not shown, the sum of the observations over the three rightmost columns does not equal the number of firms in the sample.

Source: Authors’ calculations based on the firm financial accounts database Dafne and the bank financial accounts database Bankscope, 2006-2010; growth rates also use 2005.

Table A 2: Bank Characteristics by Bank Type

	Trading vs. non trading banks		Type of bank		
	Non-trading banks	Trading banks	Savings bank	Local cooper. banks	Other banks
Total assets in thd. euro	1 236 556	19 528 038	2 286 046	563 498	11 723 731
Credit supply in thd. euro	707 082	7 018 795	1 360 294	327 167	4 236 078
Credit supply over total assets	0.571	0.554	0.578	0.580	0.552
Long term credit supply in thd. euro	393 176	2 735 758	867 179	200 233	1 586 756
Long term credit supply/total assets	0.339	0.337	0.368	0.353	0.310
Other earning assets over total assets	0.380	0.402	0.380	0.371	0.400
Share deposits to total assets	0.881	0.860	0.891	0.877	0.865
Gains from proprietary trading	15	614	221	17	229
Savings bank	0.163	0.631	1	0	0
Local cooperative bank	0.350	0.120	0	1	0
Other bank	0.487	0.249	0	0	1
Bank-year observations	4 977	1 663	1 860	1 941	2 839

Notes: The table shows mean bank characteristics by bank type for the banking partners of firms in the sample. Banks are defined as trading banks if they have nonzero gains or losses from proprietary trading activities in 2005 and 2006.

Source: Authors' calculations based on the bank financial accounts database Bankscope, 2006-2010; growth rates also use 2005.

Table A 3: First Stage Results

Dependent variable:	Lagged credit supply, growth rate	Lagged long-term credit sup., gr. rate	Including US affiliates	
			Lagged credit supply, growth rate	Lagged long-term credit sup., gr. rate
Lagged gains from proprietary trading / financial assets	2.527*** (0.144)	0.832*** (0.066)	1.979*** (0.154)	0.963*** (0.097)
Share of savings banks in distress * in and after 2007	-0.024*** (0.001)	-0.015*** (0.001)	-0.031*** (0.001)	-0.016*** (0.001)
Share of savings banks in distress	0.001*** (0.000)	0.007*** (0.001)	0.022*** (0.001)	0.015*** (0.001)
Share of banks with US affiliates * in 2008			-0.495*** (0.013)	-0.081*** (0.008)
Share of banks with US affiliates			0.297*** (0.003)	0.116*** (0.002)
D.Business tax rate	0.175*** (0.051)	0.055 (0.041)	-0.169*** (0.049)	-0.083** (0.040)
L.D.Business tax rate	-0.604*** (0.073)	-0.491*** (0.053)	-0.316*** (0.059)	-0.508*** (0.050)
Year dummies	yes	yes	yes	yes
Constant	0.020*** (0.001)	0.018*** (0.001)	-0.001* (0.001)	0.010*** (0.001)
Number of observations	291 079	291 079	291 079	291 079

Notes: The table shows the first stage results for the second stage IV regressions in Table 4 and Table 5. The two rightmost columns pertain to the IV estimations with the share of banks with US affiliates among a firm's banking partners in 2008 as additional excluded instruments. The first and third columns are the first stages when credit supply is the endogenous explanatory variable, and the second and forth columns when long term credit supply is considered instead. In the 2SLS estimation, the first stage is identical regardless of whether liabilities (Table 4) or fixed assets (Table 5) are the dependent variable in the second stage. The growth rates are log approximations. The growth rate of (long-term) credit supply, the share of savings banks in distress and the share of banks with US affiliates pertain to the firm's relationship bank(s). We link firms to their banking partners via information on individual firm-bank relationships. If a firm has multiple relationship banks, we calculate the mean of the (long-term) growth rates of their credit supply. D. indicates the first time difference of a variable and L. lagged values. Standard errors are robust to heterogeneity and clustering at the firm level. ***/**/* indicate significance at the 1%/5%/10%-level.

Source: Authors' calculations based on the firm financial accounts database Dafne and the bank financial accounts database Bankscope, 2006-2010; (lagged) first differences also use 2005 (2004).

Table A 4: Robustness Check: Credit Growth of the Best Relationship Bank

2SLS regressions of firms' liabilities and fixed assets growth rates on the maximum credit supply growth rate of its banking partners

Dependent variable:	Firms' liabilities, growth rate			Fixed assets, growth rate	
	(1)	(2)	(3)	(4)	(5)
Credit supply, maximum growth rate (i)	0.019 (0.031)				
L.Credit supply, max. growth rate (ii)	0.161*** (0.048)	0.130*** (0.042)	0.130** (0.059)	0.086*** (0.033)	0.094** (0.047)
D.Business tax rate	0.206 (0.247)	0.196 (0.247)	0.732 (0.449)	-0.374* (0.217)	-0.649* (0.377)
L.D.Business tax rate	-0.019 (0.279)	-0.023 (0.280)	0.096 (0.400)	-0.573** (0.240)	-0.763** (0.344)
L.D.Sales			0.137*** (0.008)		0.116*** (0.006)
Share of savings banks in distress	0.004 (0.003)	0.003 0.130***	0.001 (0.005)	0.005** (0.003)	0.013*** (0.005)
Year dummies					
Constant	0.003 (0.006)	0.007 (0.005)	0.011 (0.007)	-0.004 (0.004)	0.004 (0.006)
Number of observations	291079	291079	88153	291079	88153
Shea's Partial R^2 for (i)	0.07	0.03	0.04	0.03	0.04
1 st stage F -statistic for (i)	102.39	384.00	327.67	384.00	327.67
Shea's Partial R^2 for (ii)	0.03				
1 st stage F -statistic for (ii)	267.51				
Hansen test: p -value	0.41	0.78	0.19	0.53	0.31
Excluded instruments	IV set 1	IV set 2	IV set 2	IV set 2	IV set 2

Notes: Estimations at the firm-level. The dependent variable is the firm-specific growth rate in liabilities or fixed assets. The growth rates are log approximations. The growth rate of (long-term) credit supply, the share of savings banks in distress, and the share of banks with US affiliates pertain to the firm's relationship bank(s). We link firms to their banking partners via information on individual firm-bank relationships. If a firm has multiple relationship banks, we calculate the *maximum* growth rate of (long-term) credit supply of the banks here. D. indicates the first time difference of a variable and L. lagged values. Standard errors are robust to heterogeneity and clustering at the firm level. ***/**/* indicate significance at the 1%/5%/10%-level. The growth rate of credit supply and its first time lag (L.) are treated as endogenous. In the different specifications we use alternative sets of excluded instruments.

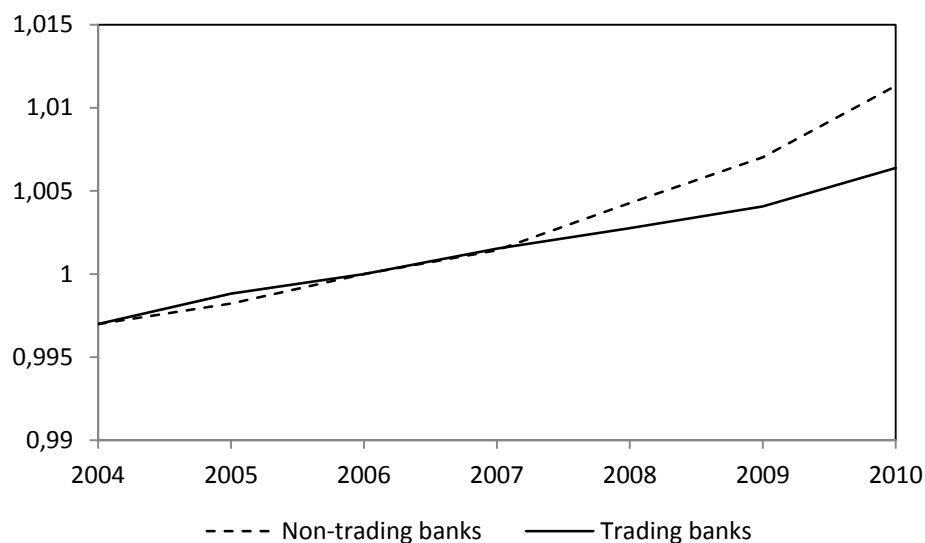
IV set 1: Proprietary trading gains and the share of savings banks in distress during the crisis among a firm's 2006 set of relationship banks in 2007 onwards. Contemporaneous and lagged variables.

IV set 2: As IV set 1, but with lagged variables only.

Source: Authors' calculations based on the firm financial accounts database Dafne and the bank financial accounts database Bankscope, 2006-2010; (lagged) first differences also use 2005 (2004).

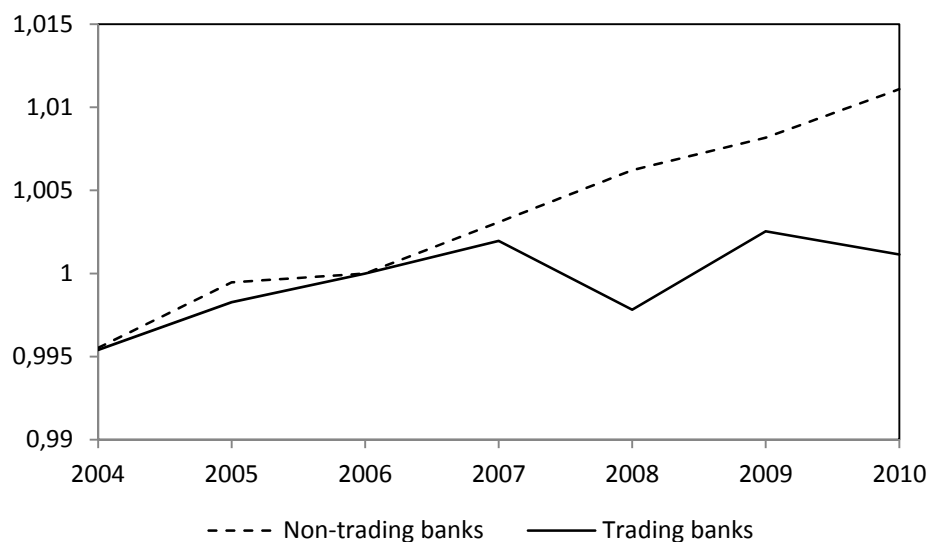
Appendix Figures

Figure A 1: Growth of Credit Supply by Trading and Non-trading Banks



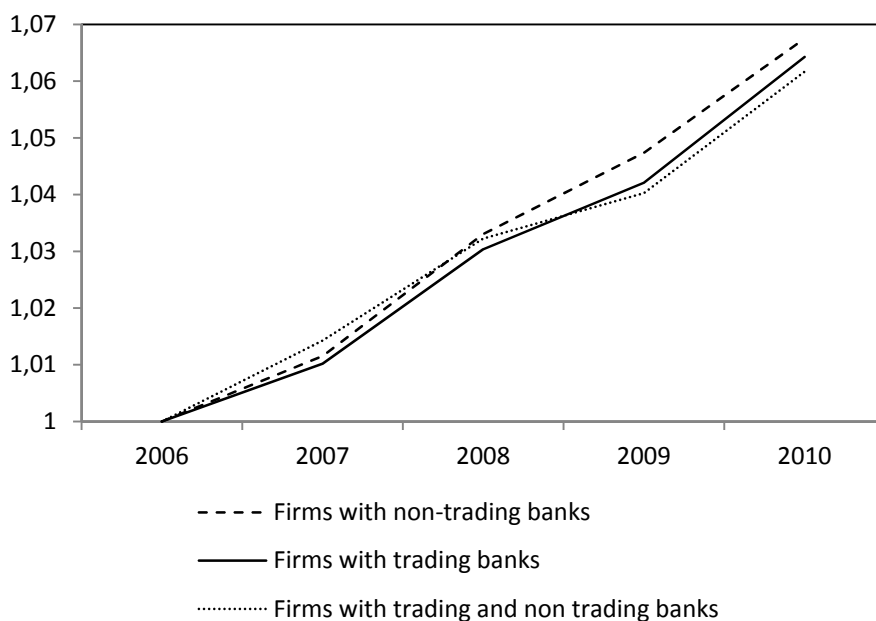
Notes: The figure shows the change in the banks' credit supply since 2006 on a logarithmic scale. We distinguish between banks that do and those that do not report gains or losses from proprietary trading in 2005 and 2006.
Source: Authors' calculations based on the bank financial accounts database Bankscope.

Figure A 2: Growth of Long-term Credit Supply by Trading and Non-trading Banks



Notes: The figure shows the change in the banks' *long-term* credit supply since 2006 on a logarithmic scale. We distinguish between banks that do and those that do not report gains or losses from proprietary trading in 2005 and 2006.
Source: Authors' calculations based on the bank financial accounts database Bankscope.

Figure A 3: Growth of Fixed Assets of Firms with Trading and Non-trading Banking Partners



Notes: In this figure, we distinguish between firms with banking partners that do and that do not engage in proprietary trading in 2005 and 2006, as well as firms with business relationships to both types of banks. For the three groups of firms, the figure shows the change in the stock of fixed assets since 2006, i.e., net real investment, on a logarithmic scale.

Source: Authors' calculations based on the firm financial accounts database Dafne and the bank financial accounts database Bankscope.