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Lu Zhang,[1] Arzu Uluc [2] and Dirk Bezemer[3]

Abstract

Was the bank credit crunch following the collapse of Lehman Brothers in September 2008 in many economies due to a loan supply collapse or to a decrease in loan demand? This paper investigates the effects of UK banks' pre-crises exposure to residential property markets on their post-crisis business lending to explore the existence of a negative post-crisis loan supply shock. We isolate the loan supply effect from a loan demand effect by using a unique quasi-experimental setting and a rich, tailor-made micro-level data set on bank lending volumes, bank balance sheets and mortgage loan characteristics. Controlling for a range of bank-specific factors, we find that banks with larger shares of residential mortgages in total loans in 2008 Q2 reduced their lending to business more after 2008 Q3. Post-crisis lending to business is also sensitive to the riskiness of banks' mortgage portfolios. Banks having more mortgages to borrowers with impaired credit history, or more mortgages to the self-employed, or mortgages with higher loan to value ratios prior to the crisis reduced their lending to non-financial businesses more.

Key words: Credit crunch, bank balance sheets, mortgage lending, micro data, United Kingdom.

JEL classification: E2, E32, E51.

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1. Introduction

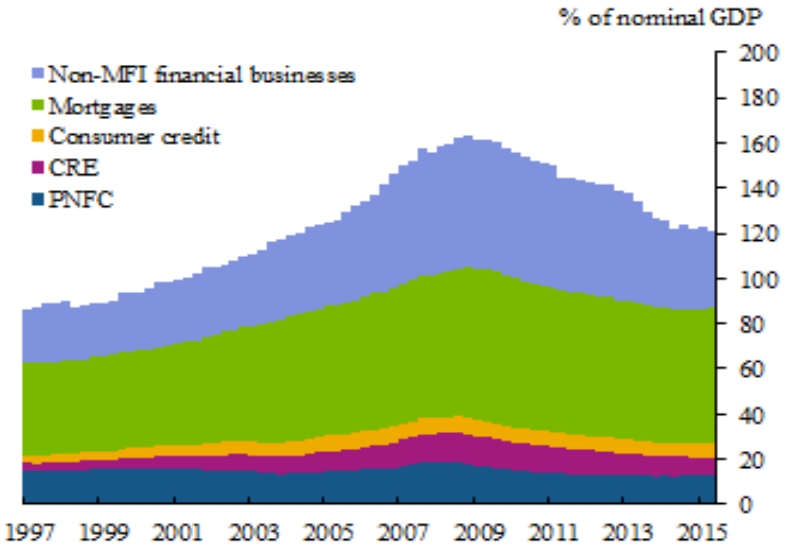
A number of recent cross-country studies find that the pre-crisis expansion of household credit increased both the crisis probability and the severity of post-crisis recessions (Jappelli et al., 2008; Barba and Pivetti, 2009; Büyükkarabacak et al., 2010; Rose et al., 2011; Frankel et al., 2012; Sutherland et al., 2012; IMF 2012; Maddaloni and Peydró, 2011; Babecky et al., 2013; Didier et al., 2012). Other studies show that growth in residential mortgages constituted the largest part of growth in household credit (Bezemer et al., 2016; Jorda et al., 2016). Taken together, these macroeconomic studies suggest that on average across countries, more residential mortgage lending before the crisis strongly correlates to financial fragility and deepened recessions after the crisis. Although establishing the direction of causality is a challenge, if we accept that causality runs from pre-crisis private debt levels to post-crisis recession severity as suggested by some previous studies (Berkmen et al., 2014; Jorda et al., 2016) it is important to understand the transmission channels.There are two broad explanations: demand-side vs supply-side effects of higher pre-crisis residential mortgage levels on post-crisis recovery.

The purpose of this paper is to explore the supply channel by investigating the role of banks` residential mortgage exposure in explaining the post-crisis slowdown in their lending to businesses. To do so, we exploit a quasi-experimental setting and a rich proprietary data set for UK banks, which enables us to isolate the supply channel from the loan demand channel. We will present evidence for a negative loan supply shock to businesses proportional to the UK bank´s residential mortgage holdings.

Similar to other countries (Bezemer et al., 2016), in the UK, residential (and commercial) property lending as a share of GDP rose significantly since the 1990s (Figure 1). Meanwhile, loans to private non-financial corporations (PNFC) declined considerably after the global financial crisis in 2008, which

had a big impact on the UK economy. In this paper we ask if the two trends are connected.

Figure 1: Bank loan stocks in the UK, 1986-2014



Source: Bank of England

Note: CRE = bank lending to Commercial Real Estate; PNFC = bank lending to private non-financial corporations.

This paper exploits the global financial crisis which was provoked by the bankruptcy of Lehman Brothers in September 2008 and traces its effect on UK banks' lending to UK non-financial non-property–related corporations, and how this was affected by their sheet exposure to residential property markets. Crucially, our approach does not require us to assume that the crisis itself was exogenous.

Our empirical methodology relies on a rich, tailor-made data set on 76 banks in the UK. This contains detailed information on each bank's loan portfolio composition. A unique feature is that we not only observe the size of residential mortgages on banks' balance sheets, but also have comprehensive information on the borrower and loan characteristics of all new mortgages issued prior to the crisis. This information allows us to observe banks'

residential mortgage exposure both in terms of volumes and characteristics. The combination of a quasi-natural experimental setting and a unique data set enables us to disentangle the household balance sheets transmission channel from a bank balance sheet channel. This allows us to provide new micro-level evidence on the effect of bank balance sheet exposure to residential property markets at the onset of the global financial crisis on post-crisis business lending growth.

There are two key findings. First, bank balance sheets indeed appear to have been a channel from the pre-crisis household debt buildup to the post-crisis fall in lending to business. Our findings suggest that this fall was at least partly a supply effect on lending. Specifically, we find that banks with larger shares of residential mortgages in total loans in 2008Q2, reduced their lending to business more after 2008Q3 until 2013Q4.

Second, we show that the riskiness of mortgage portfolios also matters. Borrower's employment status (self-employment), the share of borrowers with impaired credit histories, and mortgages with high loan-to-value ratios before the crisis are all related to less business lending after the crisis. This adds qualitative detail to our quantitative finding that exposure to the residential property market shock indeed appears to have reduced lending to business. To our knowledge, no such findings exist to date.

These results suggest that the Lehman crisis was a shock to the financial health and, therefore, lending capacity, and that reduced lending capacity was proportional to UK banks' holding of residential mortgage loans. The Lehman crisis reduced the liquidity of the securitized mortgages market, making it suddenly much harder to sell residential mortgages. To the extent that banks operated a business model based on 'originate and distribute' residential mortgages, the shock undermined that business model. The Lehman crisis and its global repercussions also sent house prices falling and

unemployment rising, reducing the collateral value of the loans and the repayment capacity of many borrowers. Also this constituted a shock to the financial health of UK banks, and undermined the quality of mortgages as a bank asset. This implies that if mortgages loans were already lower-quality pre-shock, this increased the shock effect of 'Lehman' on reduced lending capacity.

The remainder of this paper is organized as follows. In the next section we discuss the channels of transmission from high mortgage debt to post-crisis recessions, and the role of bank lending in this transmission. In Section 3 we describe our dataset and variables used. In Section 4 we discuss the identification strategy and present the empirical framework. Section 5 reports the results. Section 6 concludes with a summary, reflections on this study's limitations, suggestions for future research, and policy implications.

2. Mortgage Debt and Bank Lending: Channels and Causality

The impact of private debt levels on recession severity is subject to a challenging causality question. Unobserved factors may have caused both the pre-crisis growth in debt and post-crisis recession severity. For instance, weak fundamentals might have caused low household income growth both pre-crisis and post-crisis, compensated by debt-financed household spending pre-crisis. Two macro-data studies address this endogeneity concern. Jorda et al. (2016) use propensity score matching in data on 17 countries analyzed since 1870. Accounting for differences in country specifics in this way, they find that the aftermath of mortgage booms is characterized by recessions that are deeper, and recoveries that are slower than is the case for other booms, including other credit booms. Berkmen et al. (2014) address the causality question by using as their dependent variable the difference between ex-ante IMF predictions of income growth with ex-post realized income growth. Since

country-specific unobserved factors are included in both measures, any correlation of the difference between prediction and realization is likely to be caused by debt levels. Berkmen et al. (2014) find robust evidence for this causality.

If we accept that causality runs from pre-crisis debt levels to post-crisis recession severity, it is important to understand the transmission channels. There are two broad explanations. The first addresses demand-side effects of higher residential mortgage levels before the crisis on output growth after the crisis. High debt levels combined with falling property prices after the crisis might have induced households and firms to cut back spending more. In 'House of Debt', Mian and Sufi (2014; also, 2009) demonstrate that US homeowners with more mortgage debt before 2007 cut back their spending more after 2007. Their estimates suggest that the decline in aggregate demand driven by household balance sheet shocks accounts for almost 4 million of the lost jobs in the US from 2007 to 2009, or 65% of the lost jobs in their data. This is evidence of a 'balance sheet recession' (Koo, 2011) driven by non-bank private sector spending cuts and deleveraging, and leading to a view of the post-crisis recessions theory much like Fisher's (1933) debt deflation theory. Overall spending seems to be particularly sensitive to household mortgage debt, rather than overall private sector debt (Dynan 2012; IMF 2012).

A second explanation suggests supply-side effects of higher residential mortgages on output growth. More mortgages on banks' balance sheets might have induced banks post-crisis to reduce lending to business more when property prices were decreasing as higher the expected losses more the capital constraints. This explanation is compatible with, but different from the demand-side effect of high mortgage debts on household balance sheets just discussed. There is evidence for this effect, but not for the 2008 crisis. Gan (2007) uses matched bank-firm data to show that Japanese banks with greater

exposure to property markets prior to the 1990 Japanese property crisis, reduced their lending to business more in the early 1990s.

The focus of the present paper is on this second channel. Consider the economics of this mechanism. The assumption underpinning it is that the Lehman crisis was a shock to the financial health – and, therefore, lending capacity – of UK banks, proportional to their holding of residential mortgage loans. For this 'lending channel' to operate in this way, two conditions must be satisfied.

The first condition is that the Lehman crisis was indeed a shock to the financial health of UK banks, proportional to their holding of residential mortgage loans. There are two ways in which this condition was met, one on the funding side and one on the lending side. The Lehman crisis reduced the liquidity of the securitized mortgages market, making it suddenly much harder to sell residential mortgages. To the extent that banks operated a business model based on 'originate and distribute' residential mortgages, the shock undermined that business model. The Lehman crisis and its global repercussions also sent house pricing falling and unemployment rising, reducing the collateral value of the loans and the repayment capacity of many borrowers. Also this constituted a shock to the financial health of UK banks.

The second condition is that banks could not simply revert to pre-shock conditions by issuing uninsured debt or equity to offset a shortage of capital, and so repair their health. They were constrained in their opportunities to do so, as is indeed generally the case after market shocks (Gan, 2007; Stein, 1998).

We examine the existence of this negative bank balance sheet effect in the UK data, linking pre-crisis residential mortgage loan allocation to post-crisis growth of lending to business. There is some circumstantial cross-country evidence for a bank balance channel. Claessens et al. (2010) report that across countries, more mortgage debt increases the value of a Financial Stress Index

(FSI) designed to measure vulnerabilities in banks and other financial institutions. This indicates that residential mortgage loans affect banks' vulnerability which, in turn, may have affected lending to business. Gambacorta and Marques-Ibanez (2011) find that banks in Europe and the US with weaker core capital positions and with greater dependence on market funding and on non-interest sources of income, restricted their loan supply more during the crisis period than did other banks. Some of these characteristics (especially, market funding) correlate to mortgage debt. Jiminez et al. (2012) observe in matched bank-firm level data in Spain that banks exposed to worse economic conditions and those with lower capital or liquidity ratios substantially reduce loan granting: responding to applications for the same loan, weak banks were less likely to grant the loan. To the extent that pre-crisis residential mortgage lending lowered capital or liquidity ratios, this might be one channel of causality. These findings are relevant to our research question. In the present paper we look directly at banks' exposure to residential mortgage markets in order to find evidence on a bank balance sheet effect for the UK.

This crisis, although originated in the US, became truly global because of two main transmission mechanisms. The sudden rise in risk aversion was transmitted worldwide because financial systems are globally integrated, and banks are holding US assets. And the sudden decline in demand, especially for capital-intensive goods, was transmitted rapidly via global supply chains (Gros and Alcidi, 2010). UK's financial markets and supply chains are tightly integrated and consequently the crisis affected UK severely. These international transmission mechanisms complicate research on the causes of post-crisis economic performance, among which the post-crisis collapse in lending to business. International shock transmissions caused both shocks to domestic loan demand and shocks to domestic loan supply. To unravel these

different channels, we require data on variables that are demand-specific or supply-specific. We will employ a tailor-made, bank-level data set of loan supply-specific variables on residential mortgages.

3. Data and Variables

3.1 A new micro-level dataset on bank lending

For the purpose of our analysis, we use a unique, tailor-made database based on two sources of proprietary data from the Bank of England.[4]

The first one is a bank-level panel data with detailed information for 76 individual financial entities during the period 1997Q3 until 2013Q4. London's role as a major financial center makes the banking sector of the UK considerably more diverse. This diversity provides us a unique opportunity to exploit the variation in the size of mortgage exposure at the onset of the global financial crisis, which is a key to our identification strategy.

All institutions authorised to carry out deposit taking in the UK report to the Bank of England. This information is reported in a number of "forms". We collect quarterly data from the "BE" form on banks' loan portfolio composition, including loans to private non-financial corporations, residential mortgage loans, loans to commercial real estate, loans to other financial corporations and other loans to individuals.[5] We also collect data on disaggregated corporate lending in 13 industrial sectors from the "BE" form. This information allows us to further control for the demand-side impacts on corporate lending. We also collect other bank-level time-varying control variables from other forms.

[4] These are highly sensitive datasets and the access is only available to Bank of England staff and visitor researchers who have security clearance from the Bank of England.
[5] The BE form provides additional breakdown of liabilities to and claims on UK residents for certain items on Form BT to allow for sectoral analysis of the monetary and lending aggregates. The details of all forms can be found at http://www.bankofengland.co.uk/statistics/Pages/reporters/defs/default.aspx.

To exploit the role of risky mortgage characteristics, we merge our bank-level dataset with the Financial Conduct Authority's (FCA) Product Sales Database[6] (PSD) for a subset of 21 banks covering the period 2005Q2 till 2008Q2.[7] The PSD, covers extensive information on the loan- and borrower-characteristics for new mortgages issued prior to the crisis, such as

- size of the loan and value of the property purchased
- maturity of the mortgage contract
- loan to value (LTV) and loan to income (LTI) ratios
- interest rate type: fixed vs variable
- repayment type: capital and interest, interest only, mixed
- type of borrower: first-time buyer, home-mover, re-mortgagor
- employment status of borrower: employed, self-employed, retired or other

This information enables us to explore how the quality of mortgages, in addition to the size, matters to post-crisis bank lending in the UK.

3.2 Dependent variables

Our main dependent variable is the quarter-by-quarter percentage growth in banks' lending to non-financial corporations (excluding commercial real estate lending), defined as the quarterly net flow of corporate lending divided by the one-quarter lagged stock.

The quarterly lending growth rate exhibits considerable volatility. We follow Forbes et al. (2016) and remove the outliers with value over 100 percent. As robustness checks (results are available upon request), we also

[6] The PSD include regulated mortgage contracts only.

[7] For all mortgage lenders in our sample, we remove banks when the flow of mortgage lending is zero or negative between 2005-2008. We end up with a sample of 21 banks. These banks in total count for 26 percent of all new mortgages issued during 2005-2008.

apply two alternative ways to deal with outliers: winsorizing and trimming the bottom and top percentiles. We experimented with both 1 and 5 percentile as threshold. Our main results persist and are not driven by the way of outliers treatment.

3.3 Independent variables

Identifying the crisis

We use the collapse of Lehman brothers to identify the crisis event by constructing a 'Crisis' dummy variable, which takes value 1 after 2008Q3 and 0 otherwise.

Mortgage exposure and mortgage characteristics

To capture the size of exposure to the residential property market, we use '*Share*', which is the proportion of residential mortgages in total loans at 2008Q2.

As robustness checks, we also use the mortgage share at 2005Q3, and the change of mortgage share between 2005Q3 and 2008Q2. We check whether exposure to the commercial property market matters by constructing the share of commercial estate lending in total loans at 2008Q2 (`*CREShare*').

We have extensive information on borrower and loan characteristics of new mortgages during 2005Q2 till 2008Q2. To capture this, we construct a series of variables that measure the share of the number each type of mortgages in the total number of mortgages over the entire period.

More specifically, we analyze the borrower characteristics, such as whether a borrower's income is verified, whether a borrower has an impaired credit history, whether a borrower is self-employed, whether a borrower is a first-time buyer (FTB) and whether a borrower is a homer-mover.

In addition, we analyze the loan characteristics, such as whether a mortgage has a payment protection insurance attached, whether a mortgage is interest-only, fixed-rate, variable-rate, with maturity longer than 25 years, high LTV (i.e. LTV>75, LTV>85 or LTV>95, respectively) and high LTI ratios (i.e. LTI>3 or LTI>4, respectively).

Tables B and C in the Appendix provide detailed explanations and descriptive statistics on the mortgage characteristics used in the analysis.

Control variables

We include bank-fixed effects to control for any time-invariant bank specific factors and time-fixed effects to control for any macroeconomic factors that simultaneously affect all banks. In addition, we include a number of time-varying bank level variables. *Size* is measured as the logarithm of total assets. Following Aiyar et al. (2014), we create a bank specific measure to proxy changes in loan demand experienced by a bank, which is defined as the growth in industry-level employment, weighed by that bank's loan exposure to that industry. This ensures that the decline of post-crisis business loan growth is not driven by changes in credit demand.

In robustness checks we include additional control variables for a smaller sample (due to data limitations). These variables are *NetIncome* (net income as a share of total assets), *CostEfficiency* (total operation costs to total assets) and *Writeoffs* (write-offs of corporate loans), *Change* (1-quarter lagged change in regulatory capital requirements), *Tier1* (the ratio of Tier 1 capital to risk-weighted assets) and *CoreDeposit* (share of core deposits in total liabilities). Table A in the Appendix reports the descriptive statistics of the main variables of interest and control variables used in our analysis.

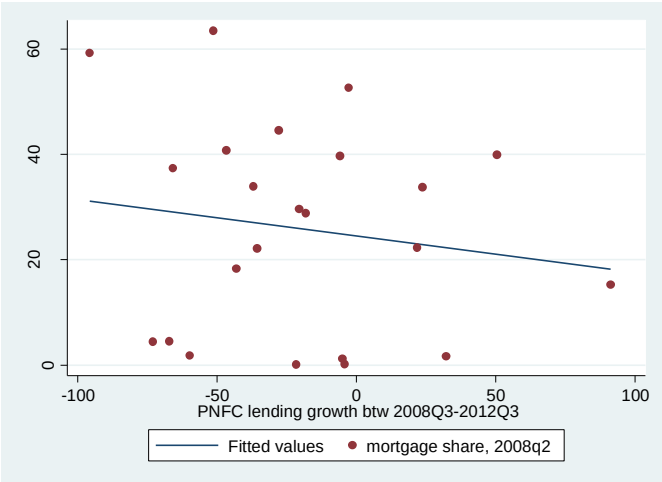
4. Empirical Methodology

4.1. Identification strategy and empirical specification

Recall that the aim of this paper is to analyze if after the global financial crisis, there was a supply-side response of UK banks' lending to businesses. We exploit the variation in the size of mortgage exposure at the onset of the global financial crisis to identify any causal effect on post-crisis business lending growth through a credit supply shock.

Figure 2 demonstrates significant cross-bank variation in mortgage exposure prior to the crisis. We also observe a negative relationship between pre-crisis mortgage exposure and post-crisis business lending growth. However, unobserved bank-level specific factors could drive this negative relationship. The decline in post-crisis lending growth could also be a reflection of weakening credit demand by non-financial corporates due to poor macroeconomic performance, rather than a decrease of credit supply by banks.

Figure 2: Banks' growth in lending to business over 2008Q3-2012Q3 (horizontal) and their share of mortgages in total loans in 2008Q2 (vertical).



Source: Bank of England

To disentangle these possibilities, we estimate the following specification:

$$\Delta \text{PNFC}_{\text{it}} = \alpha + \beta \text{Share}_i \times \text{Crisis}_{\text{t}} + \delta \text{X}_{\text{it}} + \gamma_{\text{i}} + \varphi_{\text{t}} + \varepsilon_{\text{it}} \quad (1)$$

where i denotes bank (i = 1,2, … 76) and t denotes quarter (t = 1,2, … 66, where 1=1997Q3, and 66=2013Q4). The dependent variable is the quarter-on-quarter percentage growth in banks' corporate lending. '*Crisis*' is a dummy which takes value 1 after 2008Q3 and 0 otherwise. '*Share*' is the pre-crisis residential mortgage exposure at 2008Q2. It is worth noting that `*Share*' is included as a continuous variable. We are thus able to exploit the variations in this variable and gauge the effect of increasing mortgage share on post-crisis corporate lending growth. X_{it} is a set of control variables. Finally, γ_{i} and φ_{t} are bank- and time-fixed effects, respectively.

Our coefficient of interest is β. A negative coefficient β would imply that all else equal, a bank with a larger share of mortgages prior to the crisis experienced a larger decrease in business lending growth after the crisis. This would be evidence in favour of the credit supply channel.

To further investigate the role of the quality of mortgages, we augment Equation (1) and estimate the following regression:

$$\Delta \text{PNFC}_{\text{it}} = \alpha + \beta \text{Share}_i \times \text{Crisis}_{\text{t}} + \theta \text{Characteristics}_i \times \text{Crisis}_{\text{t}} + \delta \text{X}_{\text{it}} + \gamma_{\text{i}} + \varphi_{\text{t}} + \varepsilon_{\text{it}} \quad (2)$$

All variables are defined as in Equation (1). The only difference is that we now interact the share of mortgages with particular borrower- and loan-characteristics with the crisis dummy. The coefficient on that interaction term indicates if particular mortgage characteristics play an important role in explaining the post-crisis corporate loan growth. The next section presents the empirical results.

5. Results

5.1 Pre-crisis mortgage loan share limits post-crisis corporate lending growth

Our key finding is that the estimate for β is negative, as Table 1 shows. Banks with larger shares of residential mortgages in 2008Q2 reduced their growth in lending to private non-financial corporations more over 2008Q3-2013Q4. Column (1) shows the results for the whole sample of 76 banks[8]. Based on 4,043 bank-quarter observations, the estimate suggests that a one percentage point increase in a bank's pre-crisis household mortgage share is associated with a reduction in the quarter-on-quarter growth of its post-crisis corporate lending by 0.12 percentage point. In column (2) we include only observations onmortgage lenders, reducing the sample to 1,764 observations. Despite the smaller sample, the effect is now more significant and much larger. This suggests that it is variation between banks active on residential property markets which explains the effect, rather than variation across banks which do and do not do lend to residential property.

To illustrate the economic significance, the coefficient we presented in column (2) indicate that one percentage point increase in a bank's pre-crisis mortgage share is associated with the decline of post-crisis lending growth by 0.2 percentage point. Considering that an average bank increases its mortgage share by 4.8 percentage point during 2005Q3 and 2008Q2, this translates into a reduction of business lending growth by 0.96 percentage points. The gap of pre-crisis (2.99) and post-crisis business lending growth (0.26) for a mortgage lender is 2.73 percentage point. Therefore, the mortgage exposure accounts for more than one-third of the decrease in post-crisis business lending growth, which is economically significant.

[8] Among these, 36 banks have both business and residential mortgage loans in their portfolios, while other 40 banks have business loans but not mortgages.

Table 1. Pre-crisis residential mortgage lending reduces post-crisis corporate lending growth

	(1) all banks	(2) share>0	(3) all banks	(4) share>0	(5) all banks	(6) sharechange ≠ 0
Share(2008Q2)*crisis	-0.123**	-0.206***				
	(0.0540)	(0.0663)				
Share(2005Q3)*crisis			-0.110*	-0.185**		
			(0.066)	(0.086)		
Sharechange*crisis					-0.105*	-0.105*
					(0.0535)	(0.0567)
Size	2.067***	1.193	1.781**	2.504**	1.718**	1.941
	(0.707)	-1.179	(0.736)	-1.119	(0.747)	-1.154
Demand	-0.00424	0.0439	-0.00550	0.102**	-0.0104	0.0560*
	(0.0269)	(0.0331)	(0.0274)	(0.0399)	(0.0261)	(0.0307)
Constant	-0.486	0.00753	1.837	-33.39**	2.448	-0.0756
	-5.763	-5.083	-5.900	(16.11)	-6.023	-8.282
Time-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Bank-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,043	1,764	4,024	1,604	4,024	1,987
R-squared	0.067	0.073	0.066	0.093	0.066	0.066

Notes: The dependent variable is the quarter-on-quarter percentage growth in bank corporate lending. For definitions and sources of all variables, see Appendix. Clustered standard errors are in parentheses, with *** p<0.01, ** p<0.05, * p<0.1.

5.2 Robustness Checks

Alternative definition of mortgage share

Our baseline result uses the mortgage share measured right before 2008Q3. However, it may raise the concern that the measured variations contained in the mortgage share reflect anticipated effects of the crisis. If some banks were more likely to anticipate the crisis in 2007 or even in 2006, then unobserved management quality could also explain a negative relationship between the pre-crisis mortgage share and post-crisis lending growth. And consequently, the post-crisis business lending growth declined less.

One way to ensure that the above and similar self-selection stories do not drive our results is to use the mortgage share several years prior to the crisis, assuming it is unlikely that bank managers were able to anticipate the crisis several years ahead. We use the level of the mortgage share three years prior to 2008Q3 at 2005Q3. Columns (3) and (4) in Table 1 report the results. We find that the negative β coefficients persist for the whole sample in column (3) and only mortgage lenders in column (4). Albeit with somewhat decreased significance, the magnitude of the coefficients are comparable to columns (1) and (2) in Table 1.

An alternative scenario we consider in columns (5) and (6) is that the decline could be a correction of the rapid *increase in* lending in the years preceding the crisis. Reckless lending decisions as banks scrambled to join the house price boom in the last years before the crisis might have resulted in weakened balance sheets post-crisis. We therefore investigate the impact of the increase in that share between 2005Q3 and 2008Q2 rather than its level in 2008Q3, a variable we label '*ShareChange*'. Results in columns (5) and (6) show that faster change in that share since 2005Q3 also had a negative effect on post–crisis lending to business. This result holds (unsurprisingly) both in a sample with all banks and where the mortgage share changed.

Additional Control Variables

To be able to add more bank-level control variables, we merged our dataset with the banks' profit and loss information which is available from 2004Q1, which results in a smaller sample size. The choice of control variables is motivated by the literature (Popov & Van Horen, 2015; Aiyar et el., 2014), and the results are presented in Table 2. Columns (1) and (2) include banks' net income as a percentage of total assets, operating expenses as a share of total assets, and write-offs on loans to non-financial corporations. Column (3) and (4) include the lagged change in capital requirements, the Tier-1 capital

ratio and deposits as a share of total liabilities.[9] Our main results stand, except when we include business loan write-offs. This suggests that bad loans to business on the one hand and mortgage loans on the other play much the same role in banks' lending decisions. This is in line with the view that residential mortgages weakened banks' balance sheets post-crisis: mortgage loans are treated as 'bad loans'.

Table 2. Do additional control variables matter?

	(1)	**(2)**	**(3)**	**(4)**
	all banks	**share>0**	**all banks**	**share>0**
Share(2008Q2)*Crisis	-0.117	-0.177*	-0.204**	-0.271**
	(0.0709)	(0.0907)	(0.0988)	(0.108)
Size	1.658	-0.158	3.569***	2.952***
	-1.244	-2.347	(0.850)	(0.701)
Demand	-0.0254	0.0173	0.0447	0.0660
	(0.0281)	(0.0261)	(0.0574)	(0.0650)
NetIncome	0.283	-0.00159		
	(0.754)	(0.982)		
CostEfficiency	0.812	0.152		
	(0.611)	-1.060		
Writeoffs	-3.637**	-4.831*		
	-1.493	-2.647		
Change			-72.09	-36.83
			(62.97)	(41.22)
Tier1			7.175	-0.378
			-8.301	-3.800
Coredeposite			1.677	1.044
			-3.399	-4.848
Constant	-19.73	-1.746	-30.47***	-32.41***
	(15.93)	(30.31)	-6.928	-9.110
Bank-fixed effects	Yes	Yes	Yes	Yes
Time-fixed effects	Yes	Yes	Yes	Yes
Observations	2,753	1,188	1,178	956
R-squared	0.091	0.092	0.114	0.132

Notes: The dependent variable is the quarter-on-quarter percentage growth in bank corporate lending. For definitions and sources of all variables, see Appendix A. Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

[9] Note that we cannot simultaneously include all the controls; this would reduce the sample excessively.

Different Time Windows

As another robustness check, we explored various time windows (results presented in Appendix Table D). First, we estimated Equation (1) using a smaller sample with observations starting in 2002 rather than in 1997, as in Table 1. The results are not sensitive to this; apparently they are not driven by trends and events in the 1990s, such as a longer house price boom and the dot.com turmoil in financial markets. Next, we estimate Equation (1) using observations ending in 2011. This allows us to check whether the results are driven by longer-term effects or are due to the immediate crisis effect. We find that coefficients for the immediate crisis aftermath are not much larger than the Table 1 results. This suggests that the credit supply effect of large mortgage exposure is quite persistent: pre-crisis mortgage shares influences lending to business both immediately after the crisis and in the medium term till 2014.

Bank Groups

We also estimate results at the level of bank groups, rather than individual banks. These tests for any effect of loan decisions being made at the bank group level. We find that this is not the case: the coefficients are still robustly negative, albeit smaller in the sample with mortgages than was the case in Table 1 (results presented in Appendix Table E).

Commercial real estate exposure

In the UK, both residential and commercial real estate lending increased dramatically before crises. Therefore, we also checked whether the exposure to commercial real estate lending has any effect on business lending after the crisis. We did not observe any significant effect (results presented in Appendix Table F). This is perhaps due to the fact the commercial real estate

exposure for banks, on average 10 percent, is relatively small compare to the mortgage exposure of an average bank, which is 30 percent.

5.3 Riskier mortgage exposure limits post-crisis corporate lending growth

The logic of the bank balance sheet channel which we study suggests that, in addition to the *quantity* of mortgages relative to all loans expressed in the mortgage share, also the *quality* of banks` mortgage portfolio matters. Recall that the assumption underpinning bank balance sheet channel is that the Lehman crisis was a shock to the financial health and, therefore, lending capacity, and that reduced lending capacity was proportional to UK banks' holding of residential mortgage loans, because the shock undermined the salability of mortgages and the value of collateral - in short, it undermined the quality of mortgages as a bank asset. This implies that if mortgages loans were already lower-quality pre-shock, this increased the shock effect of 'Lehman' on reduced lending capacity. We test that implication in this section.

Which features to study? The literature on drivers of residential mortgage default show that LTV and LTI at origination, mortgage term, mortgage rate type (fixed vs variable), loans to the self-employed and self-certified, and interest-only mortgages are associated with mortgage default risk (Campbell and Cocco, 2014; Herzog and Earley, 1970; Jackson and Kaserman, 1980; Quercia and Stegman, 1992; Vandell, 1995; Whitley et al., 1995; Aron and Muellbauer, 2010; Moody's, 2009; Fitch Ratings, 2010; Demyanyk et al., 2011).

We therefore include these mortgage features in the second regression presented in Section 5.1 where we include an interaction term, of mortgage characteristics with the crisis dummy.

As shown in Table 3, the interaction term of the mortgage share with the crisis dummy again carries a negative coefficient which is highly significant. We find indeed that in addition to the quantity of mortgages, also their quality matters, in various ways. Banks that carried more mortgages with payment protection in 2008Q2 reduced their lending to business less after 2008Q3. Banks having more mortgages to borrowers with impaired credit history, or more mortgages to the self-employed, or mortgages with higher LTV ratios in 2008Q2 reduced their lending to business more.

Table 3 Do Mortgage Features Matter?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
		Borrower-characteristics								**Loan-Charateristics**					
	IncVer	Impair	Selfemp	FTBs	Mover	Payprot	Interest	Fixed	Variable	>25year	LTV>75	LTV>85	LTV>95	LTI>3	LTI>4
Charac.*Crisis	-0.0125	-0.516*	-0.076**	-0.0513	-0.00075	0.495***	0.00855	-0.0485	-0.0146	0.0504	-0.100***	-0.076**	-0.057**	-0.0426	-0.0613
	(0.0299)	(0.298)	(0.0348)	(0.127)	(0.0687)	(0.112)	(0.0251)	(0.0641)	(0.0196)	(0.0377)	(0.0307)	(0.0304)	(0.0241)	(0.0791)	(0.108)
Share*Crisis	-0.210***	-0.171*	-0.243***	-0.211**	-0.220**	-0.268***	-0.204**	-0.160	-0.224**	-0.227***	-0.202***	-0.203***	-0.223***	-0.205**	-0.216**
	(0.0722)	(0.0909)	(0.0756)	(0.0855)	(0.0805)	(0.0634)	(0.0776)	(0.0966)	(0.0795)	(0.0784)	(0.0654)	(0.0691)	(0.0739)	(0.0911)	(0.0793)
Size	1.169	0.987	0.914	1.227	1.179	1.202	1.164	1.268	1.092	1.241	1.394	1.269	1.144	1.046	0.899
	(1.086)	(0.986)	(1.003)	(1.21)	(1.227)	(0.952)	(1.056)	(1.055)	(1.047)	(1.120)	(0.925)	(0.970)	(1.019)	(1.017)	(1.099)
Demand	0.0625*	0.0638*	0.0608*	0.0493	0.0498	0.0692*	0.0618*	0.0620*	0.0599*	0.0591*	0.0595*	0.0615*	0.0614*	0.0620*	0.0629*
	(0.0347)	(0.0322)	(0.0327)	(0.0299)	(0.0292)	(0.0336)	(0.0337)	(0.0331)	(0.0332)	(0.0329)	(0.0333)	(0.0335)	(0.0337)	(0.0333)	(0.0330)
Constant	-3.436	-3.833	0.782	-1.639	-1.386	-3.293	-4.950	-5.808	-2.489	-6.551	-3.897	-4.035	-3.119	-1.958	-0.735
	(7.265)	(6.632)	(7.053)	(7.739)	(7.980)	(6.771)	(7.056)	(7.295)	(6.522)	(7.981)	(6.035)	(6.646)	(6.959)	(7.646)	(8.870)
Bank-fixed effets	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,297	1,297	1,297	1,167	1,167	1,297	1,297	1,297	1,297	1,297	1,297	1,297	1,297	1,231	1,231
R-squared	0.098	0.100	0.100	0.118	0.117	0.105	0.098	0.099	0.099	0.100	0.102	0.100	0.099	0.100	0.100

Note: The dependent variable is the quarter-on-quarter percentage growth in bank lending to private non-financial corporations. For definitions and sources of all variables, see Appendix A. Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

6. Conclusion

A number of recent cross-country studies find positive effects of the pre-crisis expansion of household credit on crisis probability, on the severity of post-crisis recessions and decline in post-crises credit. A challenge in the interpretation of these findings is to disentangle the household balance sheets transmission channel from a bank balance sheet channel.

We use a quasi-experimental setting and a newly constructed data set on UK bank balance sheets to isolate the bank balance sheet effect. We investigate if after the collapse of Lehman Brothers in September 2008, there was a supply-side response of UK banks' lending to UK non-financial corporations, which depended on the banks' balance sheet exposure to residential property markets.

We find that banks with larger pre-crisis shares of residential mortgages in total loans in 2008Q2, reduced their lending to businesses more after 2008Q3. Post-crisis lending to businesses is also sensitive to residential mortgage characteristics such as the source of borrower income, the share of impaired mortgages and mortgage loan-to-value ratios. This holds on the level of both the 76 banks in our sample and on the level of the 42 bank groups they are part of. The effect is specific to residential mortgages; there is no effect for commercial real estate lending. It lasts beyond the immediate crisis aftermath.

The conclusion is that residential property markets have wide-ranging effects on macroeconomic outcomes, beyond household behavior and firm`s behavior (Bahaj et al., 2016). Banks care about their exposure - both in terms of volumes and in terms of risk - to residential property markets when they make decisions about lending to private non-financial businesses. Our paper adds to a growing literature stressing that bank balance sheets matter to real-sector outcomes.

A limitation of this study is that we have no information on demand-side conditions other than industry-level growth. The effect we find is likely to be

regionally and industry specific, and it would be important to understand better which firms and industries are more sensitive to banks' exposure to residential property markets. Another extension is to use longer time series. This is a challenge as most central banks have only recently started to collect and organize detailed bank lending data. Third, it is unlikely that these results for the UK can be extrapolated without qualification to other economies. In addition to the (now quite large) cross-country literature, one would want to see more country-specific, micro-data studies. This will help us understand variation in the effect over institutional conditions.

Our result holds significant implications for both macroeconomic research and policy. Debt, and specifically household debt, is a key determinant of the business cycle (Jorda et al., 2016). Both debt levels and qualitative features of debt contracts matter. Their study should be part not just of the field of finance, but of macroeconomics. This realization is now changing the approach to macroeconomic modelling and analysis (Jakab and Kumhof, 2015; Brunnermeier and Sannikov, 2014; Boissay et al., 2015), and our empirical work informs these efforts.

Our findings suggest that the rapid increase in mortgage lending has important implications for banks' capacity in supplying business lending subsequent to a credit shock. The decline in business lending constrained firms' productive investments (Bank of England, 2016) and exacerbated the economic recession.

Our findings also strongly support that mortgage debt should be a focal concern of macro-prudential policy. Mortgage debt is typically a stable source of income for banks, and in that sense it strengthens bank balance sheets in normal times. But mortgage debt and its securitization also create linkages between banks which increase systemic risk. This is now well understood. Our study adds to this another systemic concern: that growth in mortgage debt reduces lending to business, and thereby macroeconomic growth. We show this holds in the event of a crisis, but the effect may be more common than that. Chakraborty et al. (2016) study US loan data

before the crisis until 2006, and find that banks which are active in strong housing markets increased their supply of mortgage lending and decrease their supply of commercial lending. This implies that the development of mortgage debt needs to be monitored and assessed over the entire credit cycle.

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Appendix

Table A. Descriptive statistics

Main Variables	count	mean	sd	min	max
Corporate lending growth	4092	0.802	18.897	-95.122	97.854
Share(2008Q2)	4092	10.235	17.690	0.000	63.479
Share(2005Q3)	4073	7.983	14.675	0.000	61.945
Sharechange	4073	2.118	13.121	-35.112	63.479
Crisis	4092	0.392	0.488	0.000	1.000
Size	4092	66366.604	146977.379	16000	1257190000
Demand	3977	4.980	17.046	-89.571	147.483
CREShare	4092	10.907	12.887	0.000	46.239
Control Variables					
NetIncome	2881	0.169	0.541	-1.746	3.293
CostEfficiency	2881	0.470	0.814	0.011	7.138
Writeoffs	2880	0.074	0.282	0.000	2.325
Change	1322	-0.000	0.006	-0.049	0.049
Tier1	1853	0.151	0.113	0.018	0.829
CoreDeposit	1852	0.488	0.309	0.000	1.000

Table B. Mortgage characteristics: Definitions

Variable	Definition
IncVer	The percentage of the number of mortgages to borrowers whose income were verified to all mortgages.
Impair	The percentage of the number of mortgages to borrowers with impaired credit history to all mortgages.
Selfemp	The percentage of the number of mortgages to self-employers to all mortgages.
FTBs	The percentage of the number of mortgages to FTBs to all mortgages.
Mover	The percentage of the number of mortgages to home movers to all mortgages.
Payprot	The percentage of the number of mortgages with payment insurance to all mortgages.
Interest	The percentage of the number of mortgages with interest-only repayment (interest-only, endowment, pension, personal equity plan) to all mortgages (plus standard and other) from the SML dataset; and the percentage of the number of mortgages with interest-only repayment (ISA,

	endowment, pension, unknown) to all mortgages (plus capital and interest; and mix of capital and interest and interest-only) from the PSD dataset.
Fixed	The percentage of the number of mortgages with fix rate to all mortgages.
Variable	The percentage of the number of mortgages with standard variable rate to all mortgages.
>25year	The percentage of the number of mortgages with term above 25 years to all mortgages.
LTV>75	The percentage of the number of mortgages with LTV above 75% to all mortgages (with LTV less than or equal to 130%).
LTV>85	The percentage of the number of mortgages with LTV above 85% to all mortgages (with LTV less than or equal to 130%).
LTV>95	The percentage of the number of mortgages with LTV above 95% to all mortgages (with LTV less than or equal to 130%).
LTI>3	The percentage of the number of mortgages with LTI above 3 to all mortgages (with LTI less than or equal to 10).
LTI>4	The percentage of the number of mortgages with LTI above 4 to all mortgages (with LTI less than or equal to 10).

Table C. Mortgage characteristics: Descriptive statistics

	count	mean	sd	min	max
Borrower-Characteristics					
IncVer	1.512	64.350	34.032	0.000	100.000
Impair	1.512	1.147	2.847	0.000	13.683
Selfemp	1.512	24.641	17.049	6.091	81.509
FTBs	1.368	10.801	8.924	0.000	30.873
Mover	1.368	22.896	11.714	0.000	46.701
Loan-Characteristics					
Payprot	1.512	2.165	5.536	0.000	23.086
Interest	1.512	50.781	35.652	4.723	100.000
Fixed	1.512	27.632	27.045	0.000	96.724
Variable	1.512	35.356	41.287	0.000	100.000
>25years	1.512	14.422	21.767	0.000	98.585
LTV>75	1.512	31.022	18.947	0.000	73.397
LTV>85	1.512	20.343	18.062	0.000	71.154
LTV>95	1.512	9.548	15.005	0.000	69.872
LTI>3	1.440	35.248	14.277	0.000	71.907
LTI>4	1.440	16.899	9.479	0.000	37.599

Table D. Time window effects

	sample from 2002		*sample before 2011*	
	(1)	**(2)**	**(3)**	**(4)**
	all banks	**share >0**	**all banks**	**share >0**
Share(2008Q2)*Crisis	-0.134**	-0.205**	-0.130**	-0.233***
	(0.0646)	(0.0825)	(0.0595)	(0.0713)
Size	1.837*	0.530	0.981	1.366
	(0.974)	(1.696)	(1.280)	(1.255)
Demand	-0.0251	0.0174	0.00808	0.0875
	(0.0272)	(0.0254)	(0.0330)	(0.0594)
Constant	-39.63***	3.645	4.444	13.20*
	(8.021)	(7.150)	(10.43)	(7.032)
Observations	2,950	1,294	3,007	1,312
R-squared	0.083	0.087	0.087	0.116

Notes: The dependent variable is the quarter-on-quarter percentage growth in bank corporate lending. Bank- and time-fixed effects are included. For definitions and sources of all variables, see Appendix A. Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table E. Results for bank groups

	(1)	**(2)**
	All banks	**share>0**
Share_2008Q2*Crisis	-0.0929**	-0.106**
	(0.0405)	(0.0436)
Size	3.500***	4.068***
	(0.927)	(1.162)
Demand	0.0132	-0.0105
	(0.0503)	(0.0559)
Constant	-28.23***	-29.11***
	(7.354)	(8.195)
Observations	2,210	1,538
R-squared	0.082	0.088

Notes: The dependent variable is the quarter-on-quarter percentage growth in bank corporate lending. Bank- and time-fixed effects are included. For definitions and sources of all variables, see Appendix A. Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table F. The role of commercial real estate exposure

	(1) **All banks**	(2) **CREShre>0**
CREShare* crisis	-0.0228	-0.0247
	(0.0785)	(0.0858)
Size	1.593**	1.342
	(0.765)	(0.862)
Demand	-0.0122	0.0155
	(0.0265)	(0.0261)
Constant	5.280	-5.745
	(6.218)	(4.998)
Observations	3,977	3,343
R-squared	0.064	0.069

Notes: The dependent variable is the quarter-on-quarter percentage growth in bank corporate lending. Bank- and time-fixed effects are included. For definitions and sources of all variables, see Appendix A. Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.