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**Shocks to bank capital: evidence from
UK banks at home and away**

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Nada Mora⁽¹⁾ and Andrew Logan⁽²⁾

Abstract

This paper assesses how shocks to bank capital may influence a bank's portfolio behaviour using novel evidence from a UK bank panel data set from a period that pre-dates the recent financial crisis. Focusing on the behaviour of bank loans, we extract the dynamic response of a bank to innovations in its capital and in its regulatory capital buffer. We find that innovations in a bank's capital in this (pre-crisis) sample period were coupled with a loan response that lasted up to three years. Banks also responded to scarce regulatory capital by raising their deposit rate to attract funds. The international presence of UK banks allows us to identify a specific driver of capital shocks in our data, independent of bank lending to UK residents. Specifically, we use write-offs on loans to non-residents to instrument bank capital's impact on UK resident lending. A fall in capital brought about a significant drop in lending, in particular to private non-financial corporations. In contrast, household lending increased when capital fell, which may indicate that — in this pre-crisis period — banks substituted into less risky assets when capital was short.

Key words: Bank capital, bank lending.

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Summary

Does bank capital matter for lending? Benjamin Friedman has pointed out that a view among some economists was that holding capital was a ‘macroeconomic irrelevance’. But others counter that a shortage of bank capital leads to a fall in lending, hurting overall economic activity. For this to occur two informational failures need to exist. First, banks must have a problem raising fresh capital because potential financiers cannot tell apart a bad bank with poor lending opportunities from a good bank needing capital to fund profitable new projects. Second, borrowers must depend on bank loans in order to fund their investment because they too face problems convincing uninformed markets that they are a risk worth funding. It is easier for banks to overcome this information problem because they are better at screening potential borrowers, establishing relationships and monitoring those that they choose to finance. This means that when banks cannot lend, borrowers will in turn be unable to invest, so lowering economic growth.

In this paper, we explore what the first failure means for bank lending, that is how do banks behave when they cannot offset capital losses by raising more capital or cutting dividends? This is clearly a relevant question in the context of the banking crisis and current recession. Our empirical analysis provides a historic perspective insofar as it relates to a period preceding the current crisis. One concrete problem with much empirical work is that finding an association between bank capital and loans is not the same thing as saying that a hit to bank capital causes a drop in lending.

Non-performing loans and write-offs, which can cause banks to lose capital, tend to be negatively correlated with the economic cycle. This may mean that capital limits begin to influence the supply of bank loans when economic growth falters. But at the same time, a slowdown in growth is likely to impact individual and corporate borrowers’ incomes and net worth, their expectations about the future path of the economy and the prices of the goods and assets they want to purchase. A deterioration in economic conditions is likely to translate into lower demand for loans meaning that the supply of loans could be adjusting passively.

How is it then possible to identify and attribute lending changes to bank capital? We draw on three methods. First we take advantage of historic data on banks’ balance sheets from 1990 to 2004 to investigate shocks to different portfolio components. Along with the time dimension, we use cross-bank differences in a panel of UK banks to extract the important comovements among capital, loans, securities and liabilities. This approach, is known as a panel vector autoregression specification. We find that innovations in a bank’s capital in the sample period, other things equal, were coupled with a loan response that lasted up to three years and the effect was especially strong among small banks.

Our second method uses indicators of regulatory capital pressure from confidential supervisory returns. We use this information to test whether banks responded differently to capital innovations depending on how close they were to their minimum capital requirements set by the regulator during the sample period. Banks approaching their regulatory minimum were found to cut lending. But they also responded to an increase in capital by lending more. A further result is that banks were less



compelled to raise their deposit interest rate to attract funds when they received positive capital shocks starting from a constrained position.

Our third method is the least vulnerable to the problem that the lending response may be contaminated by demand conditions or by factors driving both demand and supply. We identify a possible exogenous shock to bank capital, in the form of a shock originating in a different geographical region. Because many UK banks take deposits from and lend to non-residents, we take advantage of data on write-offs on loans to non-residents. These write-offs will tend to reduce bank's capital (relative to the counterfactual), and are independent of a bank's lending to UK residents. For example, the East Asian crisis led to an increase in non-resident write-offs but was not associated with a rise in write-offs on resident loans. We find some evidence that a shock to non-resident write-offs caused a significant and sustained fall in UK lending. We also isolate the movements in bank capital coming from non-resident write-offs and find a significant positively correlated effect on UK resident lending (controlling for resident write-offs, liquidity and other measures). The effect was strongest on private non-financial corporation (PNFC) loans, and in contrast, lower bank capital had a positive effect on household loans. This indicates that – in this pre-crisis period – banks substituted away from risky PNFC loans into potentially less risky loans when capital was short.

The results show that the external transmission of capital shocks may be present under a more general environment than previous work, which has demonstrated a specific transmission from Japanese parent banks to their external branches in the 1990s. Second, the importance of bank capital for lending also means that the distribution of bank capital matters because information problems impede an optimal transfer of capital from capital-rich lenders to capital-poor banks. This will in turn exclude some firms from bank loans and they will also be unable to substitute to the public debt and equity markets.



1 Introduction

We revisit a long debated question of whether shocks to bank capital are important for lending, using novel evidence from a UK bank-panel that pre-dates the recent financial crisis. Focusing on bank loans, we document the dynamic response of a bank's portfolio to shocks to its capital and to its regulatory capital buffer. We also contribute to the prior literature by examining whether banks actively seek new liquidity when capital is scarce by increasing their deposit interest rate. A principal advantage of our data is that the international presence of UK banks allows us to identify changes in capital that are independent of UK banks' lending to UK residents.

Why should bank capital matter? Its relevance has sometimes been viewed with scepticism in the past. 'Traditionally, most economists have regarded the fact that banks hold capital as at best a macroeconomic irrelevance and at worst a pedagogical inconvenience' (Friedman (1991), page 240). But other economists have argued that shocks to bank capital can affect bank non-capital liabilities and bank assets, above all, bank loans, and economic activity. For example, Fisher (1933) and Bernanke (1983) stress that a bank capital crunch can lead to a fall in lending, which harms overall economic output. More recently, policymakers have injected significant equity into the banking system in order to increase capital levels and mitigate the adverse effects of bank deleveraging.¹ Critics of literature that claims to demonstrate the importance of bank capital for lending respond that the supply of bank credit is co-determined with demand for bank loans. If the economic conditions are weak or if there are negative expectations about the economy, then there will be less demand for loans. According to such critics, a decline in the supply of bank loans may reflect that fall in demand and much of the econometric literature has failed to identify the supply affect.

To assess this criticism, we identify a possible source of a shock to bank capital, in the form of an external shock originating in a different geographical region than the United Kingdom using data for 1990 to 2004. We ask whether bank loans to UK residents declined when a bank's operations abroad did poorly. We instrument bank capital with write-offs on the bank's non-resident loans, and find a significant effect on UK resident lending. The effect was strongest on private non-financial corporation (PNFC) loans, and in contrast, bank capital had a negative effect on household loans. The latter result suggests substitution away from risky PNFC loans into potentially less risky loans when bank capital was adversely affected. We also illustrate the dynamic interrelationships among capital, loans, securities and liabilities in the spirit of Hancock *et al* (1995).² Like them, we find that the duration of the loan response to a capital shock can last up to three years, and that this response was greater and lasted longer among small banks. We also touch upon the association between lending and shocks to regulatory capital, by using confidential supervisory information on

¹ For example, on 8 October 2008 the UK Treasury announced a recapitalisation plan of £50 billion, with the state injecting a substantial share in return for a share of bank ownership.

² We acknowledge the use of panel VAR programs written by Love (2001).



bank-specific minimum capital (trigger) ratios.³ A secondary contribution of our study is the application to UK data, unlike much of the literature's focus on the United States and Japan.

The remainder of this paper is organised as follows: Section 2 discusses a theoretical motivation for the importance of bank capital. Section 3 continues with a review of the prior literature, dividing it into papers that study the transmission from capital to lending, and another group that assesses the effect of bank lending on real activity. Section 4 describes the data we use and Section 5 introduces the methodology used to study the interrelationships between capital and the rest of a bank's portfolio, and discusses these results. Section 6 offers a possible driver for the documented relationship in the form of an external shock. Section 7 concludes with some policy implications.

2 A motivation for capital mattering

It is important to understand why failures in the market for bank capital imply that the allocation of capital is non-trivial. Friedman (1991) concedes that capital (and not reserves) may constrain bank credit, if we introduce minimum capital requirements. The market may also require certain minimum capital levels and this too can be a constraint. But a regulatory or a market requirement is not sufficient to ensure that banks are constrained by their capital. A bank can raise capital from other banks to meet a given requirement. Friedman notes, however, that the absence of an interbank market in capital precludes the efficient transfer of capital from banks with excess capital to those with scarce capital. This makes it significant how capital is distributed across banks.

External finance can be drawn not only from other banks, but also from a range of financial investors. Banks can raise capital in the equity and debt markets, even when an interbank market in capital is absent. But asymmetric information problems between the bank and outside financiers may impede optimal capital raising (Myers and Majluf (1984)). It may become too costly to raise capital in the outside equity market, and indeed, the cost is increasing in the risk of the claims offered to outsiders (see Calomiris and Wilson (2004), for a good discussion of the literature). The external finance premium is, also, not constant, but rises when banks may need finance most. For example, costs of issuing new equity are countercyclical. The costs of adverse selection – what is known as the 'lemons premium' – are greater during a recession, because it is more difficult for an outsider to tell apart a bad bank from a good bank with profitable lending opportunities facing a negative aggregate shock.

Although information asymmetry between insiders and outsiders plagues all firms seeking outside finance, it may be especially severe for banking firms. Bank assets can be opaque and harder to value than those of non-financial firms. Banks, as financial intermediaries, improve the allocation of

³ This paper is one of the few to make use of the trigger ratios for the period before 1996, because these are not available electronically and were inputted from hard-copy sources. The pre-1996 period is important because it captures the early 1990s' UK recession and a possible associated capital crunch.



capital among firms because they can screen potential borrowers and monitor those they choose to finance. The value of bank assets, therefore, hinges on the ability of bankers to overcome in turn asymmetric information problems with their borrowers.

If a bank cannot access new capital, and is limited by its scarce capital, it is left with the option of liquidating loans, particularly risky ones, and extending less new credit. By doing so, a bank can restore its capital and reduce its risk, as it replaces loans with more liquid assets. A bank could also attempt to retain more earnings and decrease dividends, but this is often not sufficient (and available too slowly) to insulate its loans. If many banks face similar constraints on capital and choose to cut loans, a ‘capital crunch’ can arise. That is, the scarcity of capital constrains the aggregate bank loan supply.

Several factors can lead to a ‘capital crunch’. One cause could be stricter regulation, such as the introduction of the Basel I capital requirement in 1988. For example, Thakor (1996) finds that the differential risk-weights introduced with the capital requirement led US banks to shift into lower-risk assets. Recently, Woo (2003) and Watanabe (2007) suggest that the credit crunch in Japan in the late 1990s was a regulatory-driven capital crunch. It is also feasible that when confidence in the banking sector is fragile, the market may require a larger capital cushion than is required by regulatory ratios. The collapse of asset prices is a further factor that can contribute to a capital crunch. A collapse directly reduces the market value of bank assets. But a widespread collapse in asset prices (such as land and equity) and a severe economic slowdown also increase the likelihood of borrower defaults and decrease the value of loans the bank can recover. Non-performing loans will increase and if a bank calls in a loan as past due, it may have to write off existing capital if profits are not a sufficient buffer. This may erode bank equity and decrease the capital buffer the bank has above its minimum capital requirement. The Great Depression and the early 1990s in New England and Scandinavia are episodes associated with asset price falls (see Bernanke (1983), Peek and Rosengren (1995) and Holmstrom and Tirole (1997)). More recently, this process has played out in the US mortgage market with the end of the housing boom, sharp falls in other asset prices and a widespread economic downturn. The forecast losses to banking systems vary widely across estimates. As Haldane (2009) notes ‘estimated losses within the financial sector since the start of the crisis lie anywhere between a large number and an unthinkably large one.’

A third origin of a ‘capital crunch’ derives from the bank capital channel of monetary policy. An increase in the short interest rate by the central bank may increase banks’ deposit and other liability interest rate expenses. Bank assets are, however, of longer maturity than are bank liabilities. This mismatch implies that banks cannot immediately offset the rise in interest expenses with a commensurate increase in interest income.⁴ Profits therefore fall, and bank capital may be eroded if profits turn negative (see Van den Heuvel (2002) and Bolton and Freixas (2006)). In the latter paper, tight monetary policy can cause a shift from a high-capital equilibrium to a low one, which is

⁴ An implicit assumption is that interest rate risk on the bank’s balance sheet is not fully hedged.



reinforced by the market's beliefs that in this equilibrium, a bank's decision to issue equity is a negative signal). Gambacorta and Mistrulli (2004) find support for the transmission of monetary policy through a bank capital channel, using cross-sectional evidence from a sample of Italian banks. Well-capitalised banks are better able to insulate their lending from monetary policy shocks (also see Markovic (2005) for supporting UK evidence).

Regardless of the cause, a capital crunch results in 'a significant leftward shift in the supply curve for bank loans, holding constant both the safe real interest rate and the quality of potential borrowers.' (Bernanke and Lown (1991)). That bank loans will be restricted and their cost increased only matters if there are bank-dependent firms who would otherwise not invest. This may be because firms cannot obtain arms-length financing from the capital markets. Therefore, changes in bank lending supply originating in a capital constraint will affect real activity. Holmstrom and Tirole (1997) offer a model in which an aggregate capital squeeze hurts the investment of firms with the highest agency costs (typically small and with little collateral). In their model, intermediaries, like entrepreneurs, are capital-constrained because the moral hazard problem forces them to put some of their own capital at stake. This means that an aggregate capital squeeze can have its origins in any of the three groups: firms, intermediaries, or uninformed investors. Indeed, Holmstrom and Tirole (1997) argue that the distribution of capital across 'differently informed sources of capital' (and not just banks as in the discussion by Friedman (1991)) can have real effects.

3 Prior literature

We review the prior literature by organising it into two main strands: the effect of capital on bank lending and the effect of bank lending on real activity.⁵

3.1 *Does bank capital affect lending?*

In an extensive analysis by Bernanke and Lown (1991) of whether a credit crunch was partly responsible for the US recession in the early 1990s, the authors found that bank lending was checked by a lack of capital. Their contribution was in the use of micro-based data compared with earlier aggregate studies, which were unable to satisfactorily infer the supply from the demand for loans. Bernanke and Lown (1991) found that the level of bank capital in a US state in 1989 had a positive and significant effect on a state's bank lending over 1990-91, controlling for measures of economic activity such as a state's employment growth. At an even greater zoom-in, this effect was present across banks in the state of New Jersey. Despite the strong support the authors found for a capital-driven credit crunch, they do not attribute the US recession of the early 1990s to the bank credit crunch for reasons discussed in Section 3.2.

⁵ This review is not exhaustive and we focus on more recent empirical papers.



Peek and Rosengren (1995) and Hancock *et al* (1995) are two papers that also support an important role of bank capital in explaining lending, but each taking a different approach. Peek and Rosengren (1995) focus on the New England recession in the early 1990s, and posit that the combination of stricter capital requirements and the New England property price collapse meant that banks were pushed against their minimum capital. The novelty of their test is in exploiting the deposit behaviour of banks to identify whether banks were constrained by the capital requirement or not. They show that when the capital requirement binds, an analogous feature to a fall in loans is a decline in deposits. In contrast, a bank that is able to overcome the asymmetric information constraint and raise outside funds to offset a fall in its equity, will increase its deposits. They find that New England banks were capital-constrained and deposits declined the most in poorly capitalised banks.

Hancock *et al* (1995) take a dynamic approach over a longer period from 1984 to 1993 to assess the direction, size and duration of a capital shock on a bank's portfolio. They estimate panel VARs on several hundred US banks, and find that the various components of a bank's portfolio do not adjust at the same speed. Though bank capital and the securities holdings of banks revert to mean within one year, bank liabilities and most loans take 2-3 years to adjust to a capital shock. They also find that capital shocks were twice as large in the early 1990s compared with the late 1980s, and that small banks and poorly capitalised banks experienced the greatest response and duration originating from a capital shock. Therefore, they support the hypothesis that the costs of raising outside equity are greater for smaller banks. In more recent work, Hancock *et al* (2007) also find that small businesses are more sensitive than larger ones to low capital at small banks.

Recent papers have extracted evidence from periods of severe shocks, such as the Great Depression and Japan in its recent long slump. Calomiris and Wilson (2004) take advantage of detailed individual bank data from New York City for the period before and during the Great Depression to support a 'capital crunch' in the 1930s. The novelty of their paper is the use of banking data from a period prior to the introduction of regulatory standards, which may today constrain a bank's capital and portfolio choices. This allows them to assess how banks behaved in the 'normal time' preceding the Depression, and in response to the severe shock. Banks are found to target deposit default risk by trading off their asset risk and capital ratio. During normal times when the costs of raising equity are low, banks increase their asset risk (increase the share of loans) and correspondingly increase their capital to maintain a given deposit default risk. But in times of a severe shock when the risk of deposit withdrawals rises,⁶ banks cannot increase their capital ratio because the costs of raising equity also sharply rise (see Section 2 for a motivation). Therefore, banks are forced to cut back on the share of loans on their asset side and replace the loans with cash assets, even though the latter assets do not provide the quasi-rents from risky lending. In one test of their hypothesis, they proxy differences in the costs of raising equity with cross-sectional differences in secondary market bid-ask

⁶ Aikman and Vlieghe (2004) also model a problem of information frictions between depositors and banks, which implies that depositors call for limits on their banks' leverage. Therefore, banks are forced to cut loans in response to an exogenous fall in bank capital.

spreads on bank stock. They find that banks with greater spreads issued less new stock (new stock issues dried up in 1930) and also had lower asset risk and capital ratios.

The asset price collapse in the early 1990s and subsequent slump in Japan prompted several innovative papers in the bank capital literature. Peek and Rosengren (1997) identify the transmission of a negative capital shock hitting Japanese parent bank's to their branches in the United States. They found that a bank's total US branch loans fell annually by 4% as a share of assets due to a one percentage point decrease in the parent's bank risk-based capital ratio. They convincingly isolate a bank channel, by showing that the decline in US lending was not to Japanese companies, whether based in the United States or in Japan. They also confirm that the decline in lending is not present in comparable non-Japanese banks operating in the same US state. Whereas Peek and Rosengren (1997) motivate the negative capital shock affecting Japanese banks with the decline in the Japanese asset markets, Watanabe (2007) instruments a bank's capital ratio in the 1990s with its shift to real estate in the 1980s. He finds evidence of a capital crunch in 1997. Gan (2007) exploits a unique Japanese data set, which match loans individually between a bank and a firm. He is, therefore, able to isolate the effect of a bank's health on its borrowers. For example, the same firm borrowing from two different banks, receives less credit from the bank that had more real estate exposure earlier.

A great part of the literature has focused on the United States and Japan, with few papers on the United Kingdom and other countries. Ediz *et al* (1998) are concerned with possible distortions arising from UK regulatory capital pressure. For example, whether an increase in a bank's trigger ratio (the minimum bank-specific capital ratio, below which regulatory action is taken) causes a bank to shift into less risky asset risk buckets at the expense of commercial lending. They do not find evidence of this taking place in the United Kingdom, and find that banks are unconstrained – increasing Tier 1 capital to restore capital risk-asset ratios when facing regulatory pressure. In contrast, Markovic (2005) finds evidence that UK bank lending is sensitive to capital, when looking instead at monetary policy driven capital shocks (see Section 2 for a discussion of the bank capital channel). Nier and Zicchino (2008) extend the literature with cross-country panel evidence, which supports a significant effect of bank health on lending.⁷ They find that the strength of this effect depends on the initial capital position of a bank, and is amplified during recessions when financing is difficult.

3.2 *Does bank lending affect real activity?*

Various papers offer a negative verdict on a causal effect of bank credit on real activity. Bernanke and Lown (1991) repeat their cross-sectional analysis discussed in Section 3.1, but with state employment growth as the dependent variable. Their results suggest that bank loans (instrumented with bank capital) are not significant in explaining variation in cross-state employment growth. They argue instead that a fall in the demand for credit was behind the US recession; citing evidence

⁷ Recent work by Francis and Osborne (2009) lends further support to the existence of a bank capital channel in the United Kingdom.



of an across-the-board decline in non-bank lending. More general support for an insignificant effect of bank lending on output is found by Driscoll (2004) using an elegant method. He takes advantage of the fact that the US states are small open economies with a fixed exchange rate. Therefore, any state-specific shock to money demand must be accommodated to maintain the exchange rate equilibrium. Since banks rely on deposits for loanable funds, money demand shocks will be transmitted to lending. He, therefore, instruments bank loans with money demand shocks, but finds the effect of bank loans on output to be both economically and statistically insignificant. The results of Bernanke and Lown (1991) and Driscoll (2004) suggest that US firms are not bank-dependent and are able to find alternative sources of funding.

On the other hand, there are a number of papers that give a positive verdict on a causal effect of bank credit on real activity. Bernanke (1983) finds that failed bank deposits in the 1930s contribute to explaining industrial production over and above monetary aggregates. Peek and Rosengren (2000) cleanly identify an exogenous loan supply shock stemming from the decline in Japanese lending in the United States due to parent bank weakness (see also Peek and Rosengren (1997)). They find a strong negative effect on US construction projects coming from the cut in Japanese lending. Peek *et al* (2003) instead instrument loan supply with confidential supervisory information on bank health, and also find a significant effect on the economy – even in times of strong loan demand.

Instrumented lending does especially well at explaining inventory movements, which are the component of GDP most dependent on bank loans. Aschraft (2005) exploits FDIC-induced failures of healthy bank subsidiaries to find that the decrease in bank lending led to a permanent fall in real county income of about 3%. Chava and Purnanandam (2006) use the 1998 Russian crisis as an exogenous shock to US banks to test whether a negative shock to bank health affected the stock market valuation of bank-dependent borrowers. They argue that many US banks were significantly exposed to Russia (and Brazil) but their client firms were not. They find that bank-dependent firms had a value loss of 30% (annualised) compared with firms able to reach public debt markets.

We can, therefore, conclude that the literature has identified a compelling causal relationship from bank capital to lending, but that historical evidence on the effect of lending supply on output is not conclusive.

4 The UK banking system and the data

Data on UK-owned banks' balance sheets and capitalisation are sourced from confidential monetary and regulatory returns collected by the Bank of England (on behalf of the Financial Services Authority (FSA) in the case of the latter). Gracie and Logan (2002) give an overview of both types of data and the differences between the two sources.

Since the United Kingdom's implementation of the 1988 Basel Accord in 1990, all UK-owned banks are required to complete regulatory returns to allow the banking supervisor to monitor capital adequacy. Banks complete the returns on a consolidated (worldwide) basis on a six monthly reporting cycle (which can differ between banks). Our bank sample is therefore half-yearly, and



covers data from 1990 to 2004. For this study, detailed data on each bank's risk-asset ratio (capital relative to risk-weighted assets) and its component parts have been collected. From the same source, data on deposits (split by interbank versus non-bank) and assets (disaggregated by instrument and counterparty type) have also been gathered. Unfortunately, the breakdown of assets (and in particular loans) by customer type is very limited in the regulatory returns.

Data on all UK-resident banks' lending to the different national accounts and industrial sectors are available from the returns banks make to compile the monetary statistics. Banks complete these on an unconsolidated basis on their UK-resident offices' balance sheet on common monthly and quarterly reporting cycles. The information a bank is required to provide depends primarily on its balance sheet size, and to a lesser extent, business in a particular market or sector. Therefore the monetary returns are typically completed by the larger banks.

To undertake the study, we match (as far as is possible) data on different balance sheet indicators reported in each UK-owned bank's regulatory and monetary returns. This has necessitated the manipulation of the bank's data in three ways. First, to get around banks' reporting of monetary statistics on an unconsolidated basis, the balance sheets of banks which form part of the same group have been aggregated together.⁸ This procedure known as 'quasi-aggregation' has been undertaken at end-June and end-December in each year of the sample for each bank. Another issue with the data is how to treat mergers and acquisitions (M&A). Acquirer's balance sheet variables will spike upwards on completion of the purchase. To ensure this does not affect the results of the regressions, we treat the merged entity as a new bank. For example, after the Royal Bank of Scotland's (RBS) acquisition of NatWest in 2000, the new combined bank enters the sample and the previous separate banks, RBS and NatWest drop out at that time.⁹ An alternative is to force-merge banks so that their structure throughout the sample reflects the groups' composition at the end of the sample. The results are similar if we force-merge groups, but one advantage of maintaining separate old and new banks is that it allows fixed effects for merged banks to be different. Lastly, differences in reporting cycles have been dealt with by using the prudential returns in the half year period closest to end-June and end-December.

A third source of data is hard copy information on the minimum capital requirement the banking regulator set each bank (known as the institution's trigger ratio and more recently renamed the individual capital ratio) between 1990 and 1995.¹⁰ The trigger ratio was the regulator's judgement as to the minimum level of capital adequate for the risk profile of the bank's business (see FSA (2001)). Should a bank's capital ratio breach the trigger ratio, the regulator would take disciplinary action or

⁸ Quasi-aggregation ignores the assets and liabilities of the banks' non-resident offices and potentially includes intragroup activity.

⁹ This approach will not work for the three occasions when a bank acquires a building society as data are unavailable on the mutual's balance sheet prior to the take-over. The acquiring bank's balance sheet variables are therefore scaled up prior to the acquisition by the difference in assets reported in the bank's returns made before and after the purchase. The five building societies that convert into banks via flotation enter when the institution becomes a bank.

¹⁰ These data were collected for two earlier studies Ediz, Michael and Perraudin (1998) and Logan (2000).



other enforcement actions, and *in extremis* revoke the bank's license. Note that a bank's capital requirement binds on a consolidated basis.

Given the sample period (1990 to 2004) occurs after the United Kingdom's implementation of the Basel Accord, trigger ratios are typically set in excess of the Basel minimum risk-asset ratio of 8%. This has provoked interest from other countries, given Pillar 2 (Supervisory Review) of Basel II gives regulators the ability to insist banks hold capital in excess of the 8% minimum if merited. To give a sense of the scale of trigger ratios set by the UK banking regulators, FSA (2006) shows that in 2005 18% of individual capital requirements were below 10%, 50% were set above 10% but below 15%, 21% were set above 15% but less than 20% and the remaining 6% were set above 20%.

4.1 Descriptive statistics

Table A shows some summary statistics for the main series used in the study. There is a marked decline in the number of UK-owned banks over the sample period 1990-2004, with 139 banks in the 1990 sample compared with only 48 by 2004. Most of the reduction occurs in the number of small banks in the first half of the sample (1990 to 1997). This reflects the timing of the UK small banks crisis when a number of small banks failed (see Logan (2000)) during the UK recession in 1990-91 which impacted earning streams and write-offs.

The system has also become more concentrated as the fraction of total system assets held by the big banks increased from 91% to 95%. But the structure appears more efficient (possibly due to competition) when we compare the interest rate on deposits with that on loans (the margin shrinking from 5.8% to 1.5%). Total loans from the prudential returns are not very meaningful, but more interesting stylised facts stand out in the monetary returns. Loans to UK residents as a share of total assets increased in the latter part of the sample, reflecting a sharp increase in loans to individuals, which include mortgages and credit cards.¹¹ In contrast, loans to PNFCs declined somewhat in end of sample, because firms may have had easier access to public debt and equity markets.

Finally, both the capital risk-asset ratio and the capital buffer declined equally over the sample period, which suggests that banks were holding less capital buffer above a relatively constant trigger ratio. The average capital ratio appeared high relative to the Basel 8% minimum. This reflects the number of small banks in the sample (for example, the average capital ratio for the big banks was 11.9% and the buffer was 2.7% as of end-2004. Moreover, the average capital ratio and buffer for big banks has remained relatively stable since 1997).

¹¹ The increase in the proportion of mortgage assets may be on account of the conversion of the large building societies (mutuals) into banks post 1997. All have balance sheets mainly composed of mortgage loans because of regulatory restrictions. The conversion may also explain the increase in asset concentration in the banking system.



Table A: Descriptive statistics

Date	1990H2	1997H2	2004H2
Number of banks	139	76	48
Mean assets (2001 £ millions)	5483.7	20151.3	52463.6
Median assets (2001 £ millions)	70.8	195.5	426.5
Small banks ^(a)			
Number of banks	129	64	40
Fraction of total system assets	0.09	0.05	0.05
Big banks ^(a)			
Number of banks	10	12	8
Fraction of total system assets	0.91	0.95	0.95
<i>Fraction of total assets in type category, all banks (mean)</i>			
Assets, of which:			
Investments (Securities)	0.047	0.009	0.092
Total loans (consolidated FSA returns)	0.902	0.821	0.833
of which:			
Banks & investment firms	0.329	0.358	0.329
Government & public sector	0.026	0.007	0.025
Loans secured on residential property (mortgages)	0.051	0.108	0.124
Other loans	0.474	0.334	0.351
Loans to non-residents (unconsolidated BOE returns):	0.028	0.023	0.029
Loans to UK-residents (unconsolidated BOE returns):	0.437	0.429	0.580
Private non-financial corporations (C&I)	0.124	0.142	0.096
of which: Construction & Real Estate Loans	0.068	0.045	0.041
Loans to individuals	0.227	0.221	0.379
Total liabilities, of which:			
Non-capital liabilities	0.770	0.783	0.807
Total deposits, of which:			
Bank deposits	0.177	0.093	0.090
Other non-bank deposits (household)	0.496	0.547	0.592
Marketable securities issued	0.029	0.045	0.064
Capital ^(b)	0.202	0.176	0.157
<i>Footnotes (mean)</i>			
Risk-asset ratio (%)	40.0	35.4	29.7
Capital buffer (%) ^(c)	25.8	21.5	16.8
Write-offs on loans to (2001 £ millions)			
Non-residents	23.2 ^(d)	4.7	13.4
Residents	85.4 ^(d)	53.5	110.7
Write-offs on loans to (relative to capital, %)			
Non-residents	0.589 ^(d)	0.328	0.086
Residents	6.63 ^(d)	1.62	2.82
Interest rate payable on deposits (%)	3.6 ^(e)	2.9	1.6
Interest rate receivable on loans & advances (%)	9.4 ^(e)	6.6	3.1

Source: Authors' calculations based on Bank of England monetary and FSA regulatory returns.

Notes:

^(a) Big banks are banks above the 90 percentile in terms of the fraction of total real assets of the banking system over 1990-2004.

^(b) 'Capital' refers to only the numerator used in the risk-asset ratio -- the adjusted capital base

^(c) The capital buffer is equal to the difference between a bank's risk-asset ratio and its trigger ratio

^(d) Write-off figures refer to 1993H1 for the period 1990H2 (due to data availability)

^(e) Interest rate figures refer to 1992H2 for the period 1990H2 (due to data availability)



5 The interrelationship between capital and lending

In this section, we study the effect of innovations to bank capital and regulatory capital buffer on the rest of a bank's asset and liabilities. We begin by exploring the dynamic interrelationships using panel VARs, and extend the analysis to panel fixed effects, which allow us greater degrees of freedom to focus on the association and introduce interaction terms and controls. We also address the response of a bank's deposit interest rate to the capital shock.

5.1 Methodology

We begin with a panel VAR approach, following Hancock *et al* (1995) with the goal of extracting the important comovements among the variables. We apply the Stata program used by Love and Zicchino (2006) (also see Love (2001)) to estimate a panel VAR, accounting for individual bank heterogeneity. But allowing for individual fixed effects in the presence of dependent lags in the VAR, causes the coefficients to be biased if a standard mean-differencing procedure is employed to eliminate fixed effects. Therefore, the estimation method follows Arellano and Bover (1995), which allows untransformed lagged regressors to be used as instruments because the variables are forward mean differenced, and the coefficients can be estimated by a system of generalised method of moments (GMM). The standard errors are drawn from a Monte Carlo simulation, which generates a 95 percentile confidence interval shown in the charts below. We also include time dummies to control for aggregate shocks affecting all UK banks. These dummies are eliminated by using series that are time demeaned (subtracting the means of each variable across all banks in each half-year). Most VARs employ three lags of the variables,¹² except in some cases when one lag is used because of limited degrees of freedom.

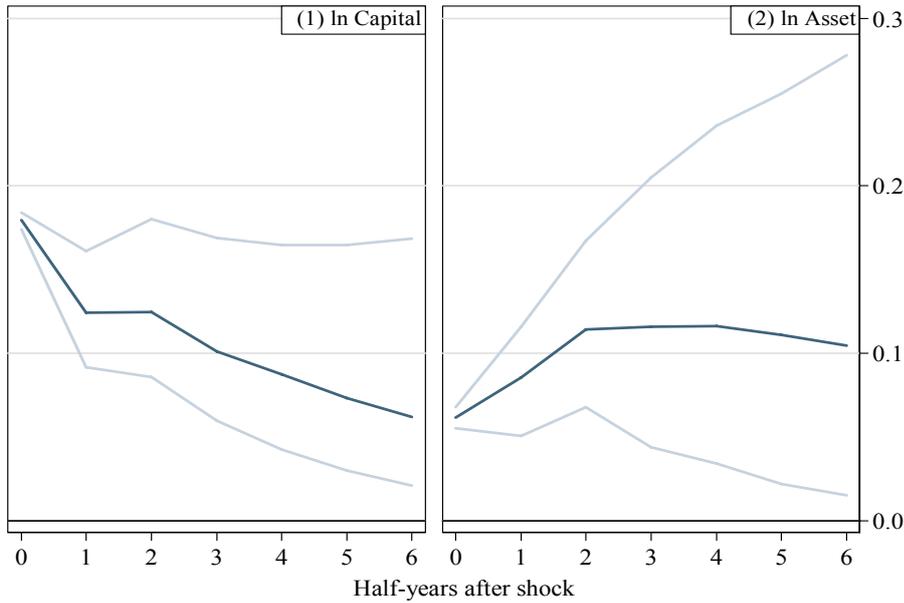
The main series of interest are bank capital, loans, investments (banks' securities holdings), and non-capital liabilities. We take variables in log form, and the impulse responses can be interpreted as constant response elasticities, as in Hancock *et al* (1995). The log specification does not constrain the responses, unlike a portfolio share specification that assumes a constant asset size. However, bank size changed in response to a capital shock as can be seen in Chart 1. Assets responded to a capital shock in the same direction, and the effect was strong and persistent. Estimating the VAR in levels may introduce non-stationarity, but Sims (1980) recommends against differencing because it throws away valuable information about the comovements in the data. We also obtain similar results when we re-estimate the panel VARs using non time demeaned series, which suggests that the assumption about unit roots is not critical.¹³

¹² Three lags are preferred based on standard information criteria applied to a VAR using aggregate time series, created by summing across all banks active throughout 1990-2004.

¹³ In only the external shock specification is there a difference, and we will discuss this result in Section 6.



Chart 1: Response of bank assets to a 1 standard deviation shock to capital



Note: The VAR model was estimated with 3 lags and the capital shock is derived from a Choleski decomposition. The ordering is adjusted capital base followed by assets. All series are time-demeaned and in logs.

5.2 Results

Having seen that assets increased in response to a positive capital shock in Chart 1, we turn to the components of a bank’s portfolio. Chart 2 shows the response of loans, securities and non-capital liabilities to a one standard deviation shock to bank capital. We use the adjusted capital base, which is the numerator used in calculating a bank’s capital risk asset ratio. The impulse responses are derived from a Choleski decomposition to orthogonalise the shocks. The ordering of the variables is as follows (and as numbered in the charts): bank capital, total loans, investments, then non-capital liabilities. This ordering means that bank capital affects the other variables contemporaneously and with a lag, but loans affect capital only with a lag, and so on. It is also reasonable to order investments (banks’ securities holdings) after loans, since they can more easily change in the current period in response to adjustments in loans and in capital than *vice versa*.¹⁴

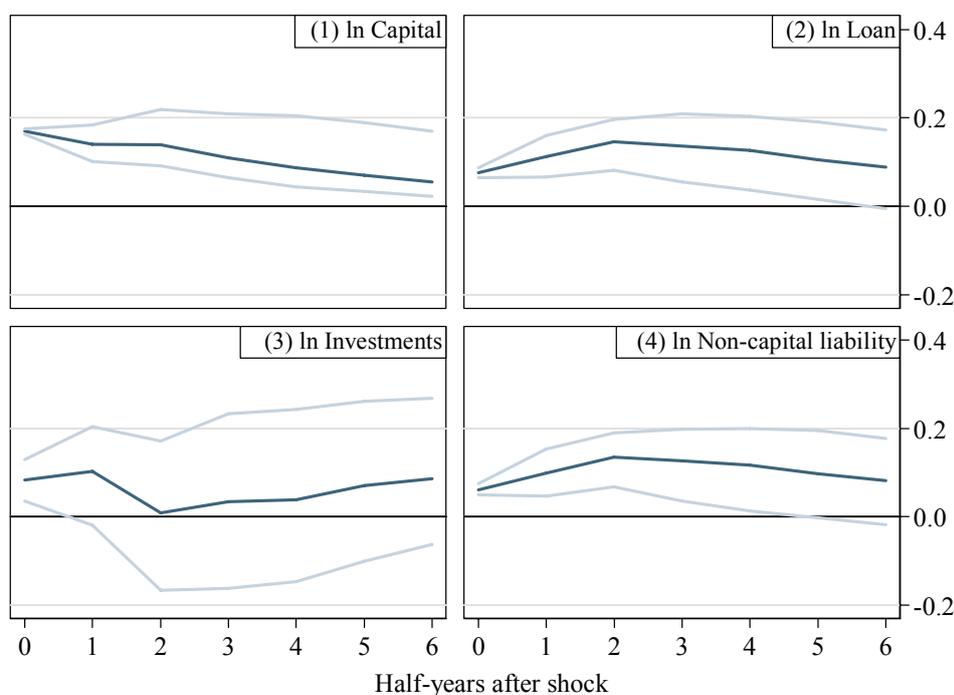
We observe that the response of loans was significant and persisted after three years. The light blue bands show the 95 percentile confidence interval around the estimate. The strong and persistent loan response is at odds with Ediz *et al* (1998) who do not find that risky lending declined when there was

¹⁴ Note that the results are similar if we change the ordering; for example, by ordering capital last and therefore allowing bank capital to adjust contemporaneously to shocks to all the other components of the balance sheet. The magnitude of the lending response to capital shocks is weaker in these cases but qualitatively similar.

an adverse shock to capital. They, therefore, conclude that (regulatory) changes in capital requirements do not result in distortionary effects on a bank's asset portfolio. A possible reconciliation of the different results is that Ediz *et al* (1998) specify asset components as a share of total assets. But we have seen in Chart 1 that total assets change in the same direction as the capital shock, which may wipe out the effect when looking at portfolio shares.

Investments tended to increase in response to a capital shock but the effect was insignificant. It is interesting that non-capital liabilities responded in the same direction as the capital shock. This goes against one prior that deposits can be used to make up for capital shortfalls. The result suggests that banks may have been constrained as discussed in Section 2, supporting the results found by Peek and Rosengren (1995) and Hancock *et al* (1995) for the 1990s. In contrast, Hancock *et al* (1995) found a negative contemporaneous response of liabilities to a capital shock in the 1980s, which they interpret as less pressure on US banks to shrink in response to a negative capital shock in the earlier period.

Chart 2: Response of bank portfolios to a 1 standard deviation shock to capital



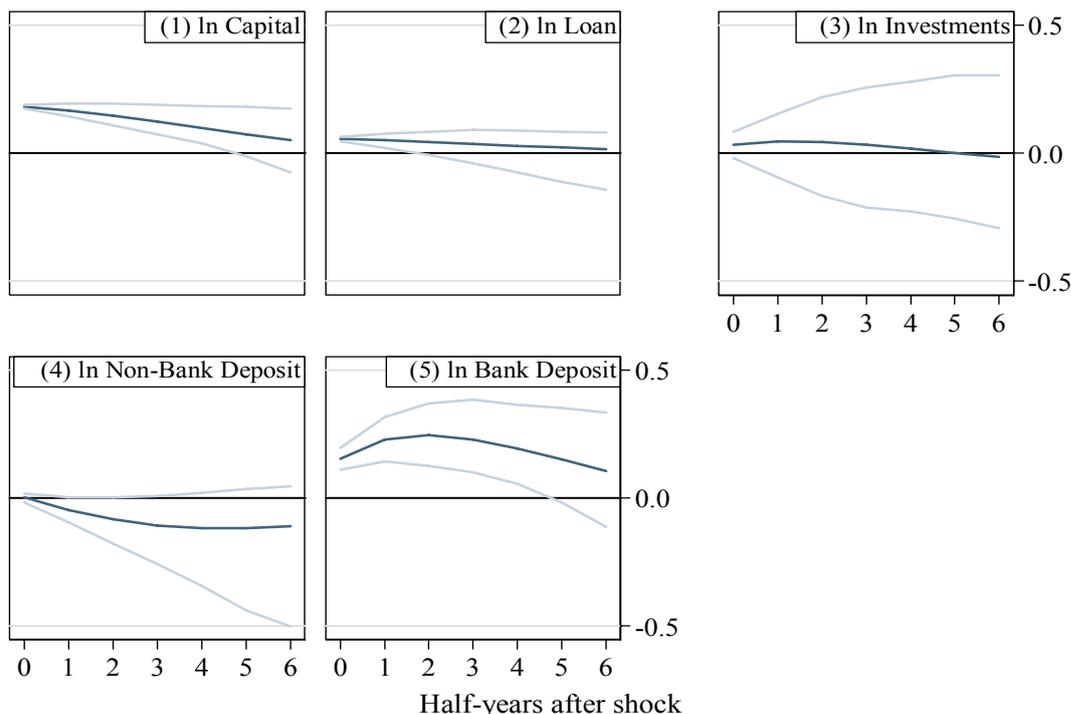
Note: The VAR model was estimated with 3 lags and the capital shock is derived from a Choleski decomposition. The ordering is adjusted capital base, loans, investments, and then non-capital liabilities. All series are time-demeaned and in logs.

If we disaggregate non-capital liabilities into interbank deposits and non-bank deposits,¹⁵ we notice that the response differs for each category. Chart 3 shows that whereas interbank deposits reacted in the same direction as the capital shock, non-bank deposits (comprising household and corporate

¹⁵ Deposits made by banks are the only term that directly refers to bank claims on the liability side of the balance sheet in the FSA regulatory returns. Non-bank deposits are calculated as a residual term (total deposits – interbank deposits).

deposits) were used to offset (partially) a capital shock. That is, falls in banks' capital imply that banks responded by raising non-bank deposits to partly make up for the outflow of interbank deposits. This result is reasonable to the extent that banks have more incentive (their deposits are not covered by deposit insurance) and ability to monitor the health of their counterparties in the interbank market.

Chart 3: Response of bank deposits to a 1 standard deviation shock to capital



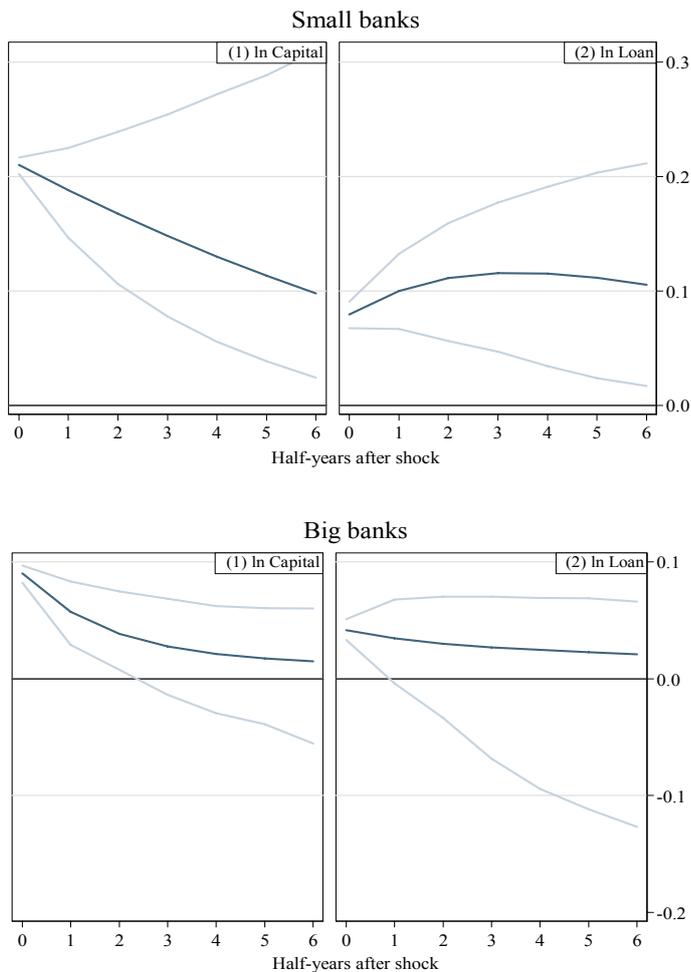
Note: The VAR model was estimated with 1 lag and the capital shock is derived from a Choleski decomposition. The ordering is adjusted capital base, loans, investments, household deposits, and then bank deposits. All series are time-demeaned and in logs.

We arrive at results in line with Hancock *et al* (1995) when we divide banks into small banks and big banks. Big banks are defined as banks in the top 10 percentile in terms of the fraction of total real assets of the UK banking system on average over 1990-2004. Chart 4 shows that small banks reacted twice as much and the response persisted, compared with a lending response for big banks that reverted to baseline after one period.¹⁶ The result is in line with the intuition that shocks to capital are more likely to alleviate finance constraints for small banks and therefore have a relatively larger impact on lending. We also divide the sample period into 1990-96 and 1997-2004,

¹⁶ The response is more easily compared by multiplying the constant-elasticity response estimates by the average share of the balance sheet component in question to assets over the entire sample period for the subset of banks as done by Hancock *et al* (1995). On impact, the capital shock is about three times larger as a per cent of bank assets at small banks compared with big banks (2 per cent compared with 0.6) and the corresponding loan response twice as large.

respectively (results are not shown in the interest of space, but are available upon request). The contemporaneous loan reaction was twice as large in the earlier period compared with the entire sample. This period includes the early 1990s' recession when there may have been a bank capital crunch (see Bank of England (1991)). But a caveat is that many small banks disappeared in the later period because of failures and mergers.

Chart 4: Response of bank loans by bank type

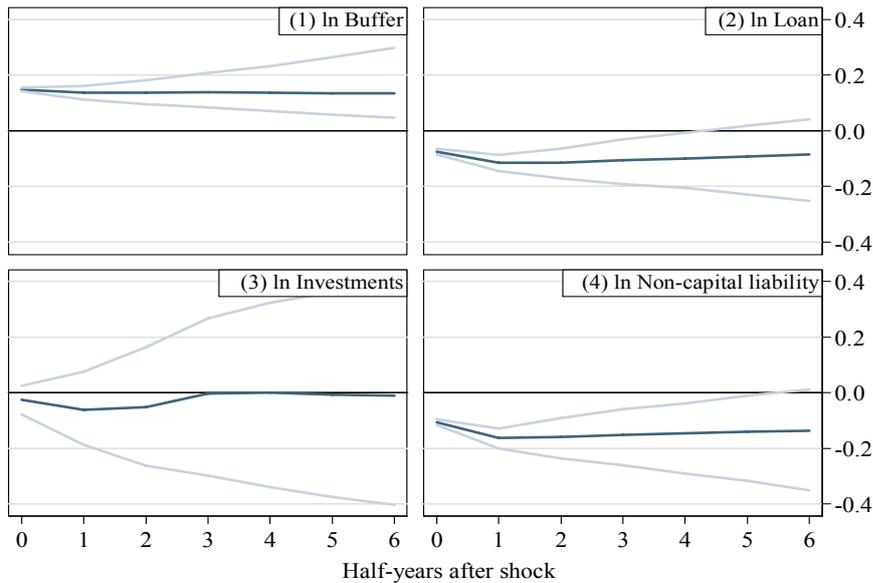


Note: The VAR model was estimated with 1 lag and the capital shock is derived from a Choleski decomposition. The ordering is adjusted capital base, loans, investments, and then non-capital liabilities (latter series not shown in interest of space). All series are time-demeaned and in logs.

We return to the full sample of banks to explore the effect of regulatory capital. A puzzle appears when we shock the regulatory capital buffer (defined as the difference between actual capital and the implied trigger capital) and we would not wish to draw firm policy conclusions from these results alone. A positive buffer shock caused a significant fall in loans and non-capital liabilities as shown in Chart 5 (and is robust to different measures of regulatory capital and variable ordering). This may capture those banks attempting to increase buffers by cutting loans. That is, the capital buffer is a

function of both the capital position and risk-weighted assets. Therefore the ordering does not guarantee that the impulses from shocks to the capital buffer can be interpreted purely as capital shocks. A second explanation may be that weakly capitalised banks ‘gamble for resurrection’ by increasing risky lending. This practice was observed in Japan in the early 1990s (see Woo (2003)), but is less plausible in explaining the UK result outside of some of the banks involved in the small banks’ crisis of the early 1990s.

Chart 5: Response of bank portfolio to a 1 standard deviation shock to capital buffer^(a)



^(a) The capital buffer in the VAR is defined as the difference between a bank’s adjusted capital base (the numerator used in the risk-asset ratio) and the bank-specific trigger capital (minimum requirement)

Note: The VAR model was estimated with 3 lags and the capital buffer shock is derived from a Choleski decomposition. The ordering is capital buffer, loans, investments, and then non-capital liabilities. All series are time-demeaned and in logs.

We turn to exploring in more detail the puzzling effect of a shock to the regulatory capital buffer from panel fixed effect regressions.¹⁷ These allow us more flexibility in identifying the response to regulatory capital shocks. For example, we can test the effect of various indicators of regulatory pressure singled out in the literature, including whether banks respond differently to capital innovations when facing such regulatory constraints. We start by documenting that lending increased when a bank’s capital buffer was large (column (1) of Table B), as we would expect if capital matters.¹⁸ But an increase in the capital buffer led to a significant fall in loans (column (2)),

¹⁷ The results of similar panel fixed effect regressions for the effect of bank capital on lending confirm the panel VAR findings (results not shown in the interest of space). The significance of bank capital (lagged per cent change) on lending is robust to including bank-specific characteristics such as log real assets and liquidity. The positive effect also translates to sectoral lending; there were insufficient observations to estimate panel VARs on the system for these as the series were obtained from the monetary returns, which are filed by the larger banks.

¹⁸ The buffer is defined as the difference between the actual capital risk-asset ratio and the trigger ratio. The result is robust to including a bank’s liquidity ratio (lagged).

which is the result also observed in the impulse responses. This result is robust to using different types of loans (by sector) as the dependent variable as well as to controlling for the change in a bank's liquidity position.

In column (3) we include two measures of regulatory pressure used by Ediz *et al* (1998): a dummy variable equal to one when the buffer is less than one bank-specific standard deviation above its trigger ratio, and a dummy variable equal to one when a bank's trigger ratio has increased within the past year. A bank falling close to its minimum capital requirement experienced a significant fall in lending, as did a bank whose supervisor raised its minimum capital requirement (although the latter result is not significant at the standard levels, but at the 11% significance level). When we interact the two measures of regulatory pressure, the interaction effect was negative, as expected, but insignificant. That is, there was no significant fall in lending when the supervisor raised the trigger ratio on a bank approaching its current trigger ratio. However, when a bank in a low buffer zone experienced an increase in its capital, it increased lending. The result is shown in column (4) and is significant at the 5% level. This result is robust to controlling for liquidity changes and the interaction of a bank in a low buffer zone with liquidity changes (column (5)). To sum up, the results of the panel VAR are consistent with the fixed effects regressions in finding that, on average, falls in capital buffers were associated with growth in lending. But those banks experiencing regulatory pressure lent more when their capital position improved.

Table B: Response of bank lending to regulatory pressure

Panel Fixed Effects 1990H1 - 2004H2

	(1)	(2)	(3)	(4)	(5)
	Dependent variable is log first difference of total loans				
Ln (Capital), Δ , lag 1				0.028 (0.057)	0.024 (0.057)
Buffer, lag 1	0.001*** (0.0003)				
Buffer, Δ , lag 1		-0.002*** (0.0005)			
Low buffer , lag 1			-0.033* (0.020)	-0.012 (0.019)	-0.012 (0.019)
Increase in trigger, lag 1			-0.050 (0.031)		
[Low buffer , lag 1] x [ln (capital), Δ , lag 1]				0.205** (0.090)	0.209** (0.090)
<i>Controls</i>					
Liquidity , Δ , lag 1					0.203 (0.138)
[Liquidity , Δ , lag 1] x [ln (capital), Δ , lag 1]					-0.036 (0.360)
Observations	2017	1883	2017	1893	1893
Banks	132	130	132	131	131
R ²	0.034	0.034	0.029	0.033	0.034

Notes:

All regressions include bank and time fixed effects.

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Standard errors are reported in parentheses.



One question that has received little attention in the previous literature is what effect a capital shock has on a bank's interest rates. The literature has focused on the response of quantities (such as the volume of loans) but has not paid attention to prices (such as the deposit interest rate). Berger (1995), however, found that higher capital ratios Granger-caused higher bank earnings in the 1980s and mainly through lower interest rates paid on uninsured funds. We expect that a bank suffering from a negative capital shock would also seek funds by offering a higher deposit interest rate. Indeed, Calomiris and Wilson (2004) argue that banks with high deposit default risk may experience some withdrawal of savings by depositors, and therefore raise their interest rate.¹⁹

A bank may also increase its loan rate, but there is a selection problem on the lending side such as a flight to quality. That is, a bank with a shortage of funds may not maintain a constant portfolio of credit risks, and may instead shift to less risky borrowers so that its average lending rate could fall. Holmstrom and Tirole (1997) refer to illustrative evidence from the Scandinavian recession, which began as a credit crunch. They point out that the gap between the lending interest rate and the deposit interest rate increased. But they acknowledge that interest rate spreads across different periods are not comparable because selection effects narrow this gap. More formal evidence is offered in Hubbard *et al* (2002) who find that less-capitalised banks ask for higher loan rates than well-capitalised banks, controlling for individual borrower risk using a matched sample.²⁰ We do not focus on the lending interest rate because of possible selection effects in our sample and present some results for the deposit interest rate in Table C.

The sample period for these regressions is limited to 1992-2004, because interest rate data are not available earlier. The sample of banks is also reduced to roughly 30 banks because not all banks are required to report this information. Column (1) of Table C shows that an adverse capital shock did not make a bank offer a higher deposit rate (if at all, the sign on the first lag is positive but not significant). There was also no corresponding increase in loan interest rates (results not shown). But deposit interest rates significantly increased when a bank's capital buffer fell, as shown in column (2) (this effect is also observed on loan rates and the interest margin). If a bank was also in a low buffer region and experienced a negative capital shock, it raised its deposit interest rate. This result is observed in the interaction coefficient in column (3), and is significant at the 10% level when liquidity changes and their interaction with the low buffer are controlled for (column (4)). The results are mixed, but regulatory-related capital considerations seem to have influenced a bank's deposit rate in the expected direction.

¹⁹ But even in a model where there is imperfect competition in the deposit market, so that banks can offer different deposit rates, information frictions between banks and depositors may constrain banks from offering higher deposit rates. This does not resolve the problem that households require banks to have a minimum capital at stake in its lending (see Holmstrom and Tirole (1997)).

²⁰ Ferri and Kang (1999) also test whether bank lending rates (on overdrafts) increased relative to corporate commercial paper rates during the Korean crisis. They find this to have been the case and that this spread increased not only for small firms but also for large firms.



Table C: Effect on deposit interest rates
Panel Fixed Effects 1992H1 - 2004H2

	(1)	(2)	(3)	(4)
	Dependent variable is the deposit interest rate, first Δ			
Ln (Capital), Δ , lag 1	0.319 (0.265)		0.789* (0.408)	0.868** (0.409)
Ln (Capital), Δ , lag 2	-0.091 (0.227)			
Buffer, Δ , lag 1		-0.033*** (0.012)		
Buffer, Δ , lag 2		-0.002 (0.002)		
Low buffer , lag 1			0.064 (0.108)	0.062 (0.111)
[Low buffer , lag 1] x [ln (capital), Δ , lag 1]			-0.780 (0.488)	-0.864* (0.489)
<i>Controls</i>				
Liquidity , Δ , lag 1				-1.365* (0.724)
[Liquidity , Δ , lag 1] x [ln (capital), Δ , lag 1]				0.643 (1.531)
Observations	384	374	387	387
Banks	31	29	29	29
R ²	0.073	0.093	0.077	0.087

Notes:

All regressions include bank and time fixed effects.

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Standard errors are reported in parentheses.

5.3 An evaluation

We have documented an association between capital and lending but the results in Section 5.2 are descriptive. They do not escape the criticism that the economy may be driving both bank capital and the demand for loans. For example, an aggregate real shock such as a terms of trade worsening negatively affects a borrower's profitability, which in turn raises the rate of non-performing loans and affecting bank health. Or that capital is endogenous to a bank's portfolio risk. For example, banks with growth prospects (and greater lending opportunities) are likely to hold more capital as a buffer because their earnings are also riskier. Using lags of capital is not sufficient because they are only predetermined but are not exogenous.

The results also indicate that banks seek funds when regulatory capital is scarce by increasing their deposit interest rate, and that lending responds to regulatory capital pressure. But there may be a condition that drives both regulatory action and bank lending, so there is an omitted variable



problem. A fall in lending may have occurred regardless of the formal action. Or that some banks are located in a region with weak loan demand, and the supervisor also raises the trigger capital ratios of these banks.

Therefore, while the results are informative about the dynamic relationships such as the duration of the shocks and regulatory feedback, we are left with the question whether a driver of these shocks can be isolated. By understanding the nature of the capital shock, we can better understand the relationships discussed in Section 5.2.

6 An external shock: a possible driver of bank capital

One transmission channel to bank capital originates outside the United Kingdom. We can isolate a possible causal role for bank capital by asking whether loans to UK residents fall when a bank's operations abroad do poorly. Because UK banks took deposits from and lent to non-residents in the sample period, we take advantage of the write-offs on bank loans to non-residents²¹ (see Table A). These write-offs may come at the expense of bank's capital, and are independent of a bank's lending to UK residents. Because the origin of these write-offs was in a different geographical region than the United Kingdom, our results are less likely to have an omitted variable bias. One caveat is that the sample is limited to roughly 30 banks since 1993 due to data availability but this size is similar to the study by Peek and Rosengren (1997).

The paper by Peek and Rosengren (1997) merits comparison. As reviewed in Section 3, the authors find that the lending of Japanese bank branches in the United States was significantly hurt by the weak capital ratios of their parent banks. This transmission from Japanese parent banks to their branches in the United States was a strong and concentrated risk. But is the reverse true? We expect there to be a stronger effect of parent companies on their branches than *vice versa*. Japanese parent bank capital was also vulnerable to the stock market collapse, which made capital requirements binding. However, can there be a similarly significant transmission for banks not suffering from a severe recession and restructuring?

The Japanese case was not only a concentrated risk, but may have contained elements that induced Japanese banks to excessively cut their US and other foreign lending. Caballero *et al* (2006) argued that, some Japanese banks continued to support unprofitable firms in Japan by rolling over their loans. This implies that Japanese banks may have been biased toward reducing their US lending through their branches rather than restructuring at home. Indeed, Peek and Rosengren (1997) point out that parent banks continued to lend domestically because they valued their historical customer relationships. This meant that the necessary loan contraction took place overseas, in order to insulate domestic loans. The effect found by Peek and Rosengren (1997) may, therefore, be exaggerated.

²¹ The write-off data to non-residents refers only to lending from UK banks' UK resident offices. It does not include their local office lending (branches and subsidiaries abroad) but may include write-offs of UK resident banks on loans to these affiliated banks abroad. Local office lending covers about half of all UK bank lending to non-residents.



For these reasons, we do not expect to find a significant effect of bank capital on lending for the UK sample. But if capital is found to influence bank lending, then capital shocks may be more important than previously thought.

6.1 *Descriptive statistics on non-resident write-offs*

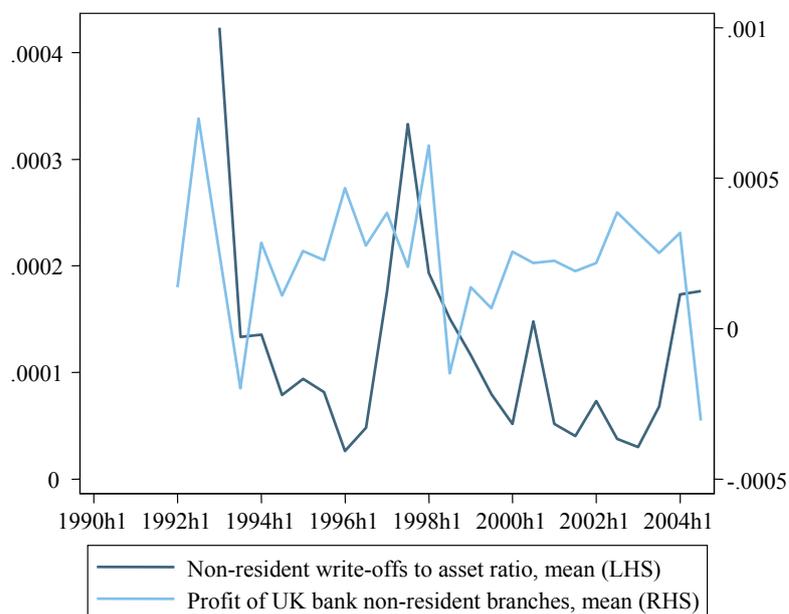
Chart 6 plots the average ratio of non-resident write-offs to a bank's total assets along with the average profits of UK non-resident bank branches over the sample period. The two series are negatively correlated (correlation coefficient equal to -0.087), as expected. Over 1993-2004, the average share of non-resident write-offs to total assets equalled 0.0126% and the standard deviation was 0.0458%. The earliest recorded non-resident write-offs in 1993 were relatively large and close to 0.04% of total assets, on account of the after-effects of the Latin American debt crisis and the Brady bond conversion deals. As shown in Table A, non-resident write-offs were at a high of an average £23 million in 1993 (in real 2001 terms). Relative to capital, this meant an average loss of 0.6% in 1993. A second rise occurs at the time of the East Asian crisis in 1997-98, and the last upsurge in 2003 has been credited to write-offs on euro loans to European non-financial companies.

Chart 7 repeats a plot of the non-resident write-off series but along with the average ratio of resident write-offs to a bank's total assets (mean is 0.266% of assets and standard deviation is 0.649%). Our identification strategy relies on non-resident write-offs being independent of resident write-offs and therefore UK resident lending. One criticism is that a global event may cause a bank's non-resident write-offs to be correlated with its resident write-offs. To address this criticism, we control for resident write-offs in the regressions later presented. Furthermore, no obvious correlation stands out in Chart 7 for 1993-2004. The correlation coefficient between the two series is 0.28 and insignificant for the entire sample. But if we exclude the sample in 1993, the correlation coefficient equals -0.11.²² The similar pattern in 1993 is most likely spurious, because of the Brady bond conversion deals (affecting non-resident write-offs) occurring with the early 1990s' UK recession (affecting resident write-offs). Note that while the global interest rate shock in the early 1980s may have contributed to both the Latin American debt crisis and to UK resident write-offs, its effect on UK resident write-offs would have also taken place in the 1980s, which is not in the sample due to data availability. In contrast, the Brady bond conversion deals associated with non-resident write-offs were only created several years later in 1989. Therefore, the evidence is consistent with the independence of non-resident write-offs from resident lending over the sample period. In addition, there is considerable bank-level heterogeneity that helps to identify the elasticity of the lending response to capital.

²² Also note that the correlation coefficient between the average resident write-off ratio based on our sample of roughly 30 banks and the aggregate resident write-off series for all UK banks equals 0.41 and is significant at the 5% level. The correlation coefficient between this aggregate resident write-off series and the non-resident write-offs for our banks is 0.03.

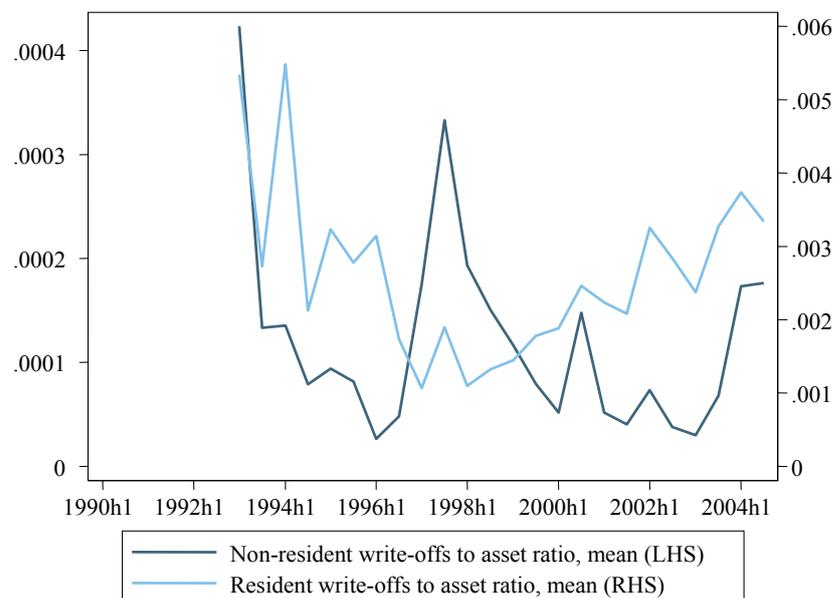


Chart 6: Non-resident write-offs and profits of non-resident bank branches



Sources: Bank of England and authors' calculations.

Chart 7: Non-resident write-offs and resident write-offs



Sources: Bank of England and authors' calculations.

6.2 Results

We first present the impulse responses from a panel VAR in Chart 8. Our interest is the response of UK resident lending to an innovation in non-resident write-offs. The ordering of the variables is as follows: non-resident write-offs, bank capital, loans to UK residents, investments, followed by non-capital liabilities. A shock to non-resident write-offs lasted for about 0.5-1 year, and caused a more persistent fall in UK lending, but was not significant at the 5% level. The capital response to an increase in non-resident write-offs was negative in the longer run but insignificant. It is interesting that capital increased on impact. One possibility is that banks recognise that they will have to write off existing capital in the future, and therefore, take defensive action to raise capital when they are hit with write-offs.

However, the impulse responses using non time demeaned series differ in this case of an external shock, unlike the panel VARs in Section 5.2 where the two gave similar results (see Section 5.1). We therefore present the impulse responses of the non time demeaned variables in Chart 9. Not only was the response of UK bank loans stronger in this case, but the effect on capital turned significantly negative and lasted for about one year. We reconcile this result with the insignificant effect on capital seen in Chart 8 as follows: the impulse responses in Chart 8 are of time demeaned variables, that is where the means of each variable across all banks in each period have been subtracted. But by controlling for time effects, we may be throwing away information about the time comovement in the data. For example, non-resident write-offs may increase for most banks in certain years (such as the East Asian crisis), and we lose the transmission to bank capital and lending when we compare responses relative to the average bank's response.

Chart 8: Response of UK-resident loans to external shock

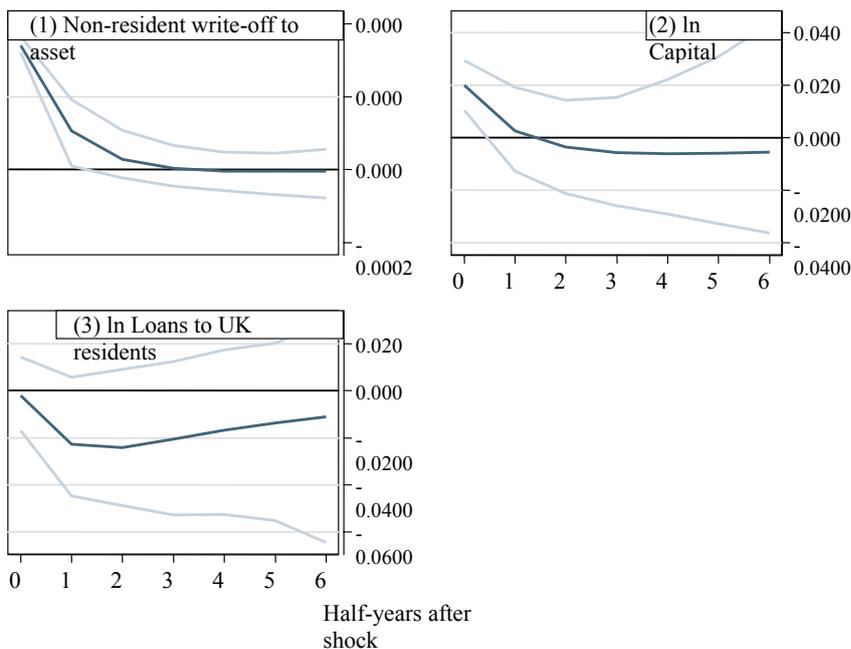
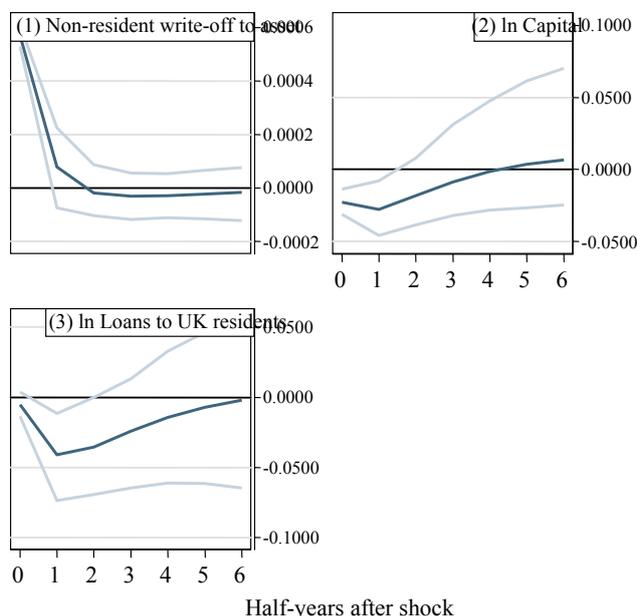


Chart 9: Response of UK-resident loans to external shock, non time demeaned series



Note: The VAR model was estimated with 1 lag and the external shock is derived from a Choleski decomposition. The ordering is write-offs on non-resident loans, adjusted capital base, loans to UK residents, investments, and then non-capital liabilities (latter series are not shown in the interest of space). This chart is similar to Chart 8, with the exception that the series are not time-demeaned.

Table D presents the results of panel fixed effects regressions, in which we instrument bank capital with write-offs on the bank’s non-resident loans. Column (1) can be interpreted as the correlation between a bank’s growth in capital and its UK resident lending growth. There was a positive effect of contemporaneous capital on lending: a 1% growth in capital was associated with a 0.28% growth in UK lending, which is significant at the 1% level. The sample is also limited to those observations for which non-resident write-offs data were available, for comparability with columns (2) – (5). The overall lending response to non-resident write-offs was negative in column (2), and in particular to lags of the non-resident write-off terms, which is in line with the duration of this external shock seen in Charts 8 and 9 (the non-resident write-off terms are jointly significant at the 10% level). The contemporaneous change in the non-resident write-offs share and its two lags are then used to instrument for capital growth in column (3). The economic impact is greater than the result in column (1): a 1% growth in (instrumented) capital increased UK resident lending by 0.67% and is statistically significant at the 10% level.²³ We control for the change in the contemporaneous resident write-offs share and its two lags in the regression in column (4). The effect of capital on

²³ We also test for overidentifying restrictions, where the null hypothesis is that the excluded instruments are valid instruments. The null cannot be rejected; the Sargan-Hansen panel data test statistic is 4.083 with a p-value of 0.13. If we also include as instruments changes (and lags) of the profits of non-resident branches, the coefficient on instrumented capital in Table D, column (3) is 0.6%, significant at the 5% level, and the Sargan-Hansen test p-value is 0.16.

lending is robust to accounting for resident write-offs. The latter entered negatively, as expected, and the contemporaneous resident write-off share was significant at the 15% level. This means that the results are not due to a common factor driving both resident and non-resident write-offs, which would contaminate the coefficient estimate on capital with domestic demand factors.²⁴ Finally, column (5) controls for aggregate GDP growth and bank-specific characteristics. A bank's liquidity share (the ratio of its investments (securities) to total assets) was positively and significantly associated with the bank's lending, and GDP growth entered with the correct sign (but was not significant). However, instrumented capital maintained a strong effect on UK resident lending.

Table D: Response of UK-resident loans to external shock: write-offs on non-resident loans
Panel Fixed Effects 1993H1 - 2004H2

	(1)	(2)	(3)	(4)	(5)
	Dependent variable is the log first difference of loans to UK residents				
Ln (Capital), Δ	0.279*** (0.076)		0.665* (0.363)	0.738** (0.335)	0.833** (0.375)
Non-resident write-off to asset ratio, Δ (NRW)		33.00 (21.03)			
NRW, lag 1		-30.83 (22.21)			
NRW, lag 2		-26.58 (22.37)			
<i>Controls</i>					
Ln (GDP), Δ					0.331 (1.576)
Resident write-off to asset ratio, Δ (RW)				-3.033 (2.041)	-3.565* (2.046)
RW, lag 1				-0.820 (2.431)	-1.352 (2.423)
RW, lag 2				-0.978 (2.080)	-1.129 (2.104)
Ln (Real Asset), lag 1					0.043 (0.036)
Liquidity, lag 1					0.236* (0.124)
<i>Instrumenting capital?</i>	No		Yes, with non-resident write-off to asset ratio, Δ , current and 2 lags		
Observations	313	313	313	305	305
Banks	29	29	29	28	28
R ²	0.105	0.087	0.018	0.009	-

Notes:

All regressions include bank and time fixed effects, with the exception of model (5), which omits time dummies due to the inclusion of GDP growth. No (within) R² is reported in column (5) because it can sometimes be negative in instrumental variables estimates, even when a constant is included.

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Standard errors are reported in parentheses.

²⁴ The results are also robust to the exclusion of observations in 1993-94, when resident and non-resident write-offs were positively correlated. The results are also robust to the exclusion of nine banks with positively and significantly correlated resident and non-resident write-offs over the sample period.



Regressions for the different sectors of UK resident lending are shown in Table E. Lending to private non-financial corporations (PNFC) was negatively affected by non-resident write-offs as shown in column (1). The instrumental variables estimates in columns (2) – (5) show that capital had the strongest effect on PNFC loans, whereas, bank capital negatively affected household loans. A 1% growth in capital (instrumented) increased PNFC loans by 1.06% but caused household loans to fall by about 3%. These results are robust to controlling for resident write-offs, GDP growth, and bank-specific characteristics, as in Table D (results not shown). Capital also entered positively in lending to construction & real estate and credit card loans (a component of household loans), but the coefficient was not statistically significant. We interpret these results as possible evidence of asset risk substitution behaviour in response to a capital shock in the sample period. For example, a negative capital shock caused banks to substitute from PNFC loans into household loans (that include mortgages). It is important to bear in mind that this could reflect a sample-specific result. For example, mortgage loans have only a 50% weight under Basel 1 compared with 100% for PNFC loans, so switching into mortgage loans would boost a bank's risk-adjusted capital ratio.

Table E: Response of UK-sectoral loans to external shock: write-offs on non-resident loans
Panel Fixed Effects 1993H1 - 2004H2

	(1)	(2)	(3)	(4)	(5)
	Dependent variable is the log first difference of loans to UK residents:				
	PNFC loans	PNFC loans	Construct- ion & RE loans	Individual loans	Credit card
Non-resident writeoff to asset ratio, Δ (NRW)	44.40** (21.49)				
NRW, lag 1	-41.33* (22.67)				
NRW, lag 2	-47.43** (22.77)				
Ln (Capital), Δ		1.056** (0.421)	0.068 (0.577)	-2.994** (1.284)	0.936 (1.891)
<i>Instrumenting capital?</i>		Yes, with non-resident writeoff to asset ratio, Δ , current and 2 lags			
Observations	248	248	245	294	184
Banks	23	23	22	25	15
R ²	0.203	-	0.106	-	0.159

Notes:

All regressions include bank and time fixed effects.

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Standard errors are reported in parentheses.

Results are robust to inclusion of controls used in Table D (4).

To summarise, the results indicate that the effect of bank capital was economically significant on lending. A 1% fall in (instrumented) capital reduced UK resident lending by 0.67%. These results are comparable with Peek and Rosengren (1997) who found that a bank's total US branch loans fell 6% due to a one percentage point decrease in the Japanese parent bank's risk-based capital ratio.



This implies an elasticity of 0.48 if we evaluate the one percentage point fall in capital from an initial capital ratio of 8%. The recent estimates by Greenlaw, Hatzius, Kashyap and Shin (2008) suggest that a \$100 billion fall in capital could lead to a \$910 billion fall in US bank lending. These figures roughly translate to a 5% capital fall leading to a (greater) 10% fall in loans.

7 Conclusion

The results of this paper can be summarised as supporting a causal role of bank capital on lending. We began by documenting the dynamic interrelationship between capital and a bank's portfolio, focusing on bank loans. We also found that lending responded to regulatory capital pressure. For example, a bank whose capital was close to its minimum capital requirement, responded to an increase in its capital by lending more. At the same time, it was less compelled to raise its deposit interest rate when it received this positive capital shock. While these findings are informative about dynamics and regulatory pressure, they point to an association between capital and a bank's portfolio decisions, without identifying a driver of capital shocks. We, therefore, take advantage of the widespread overseas ties of UK banks in the sample period, which allow us to isolate a shock to bank capital, independent of their lending to UK residents. We use write-offs on loans to non-residents to instrument bank capital's impact on UK resident lending. Because the origin of these write-offs was in a different geographical region than the United Kingdom, our results are less likely to have an omitted variable bias.

This external transmission mechanism is present under a more general environment than the long Japanese recession in the 1990s. This result is also consistent with the spread of the Russian crisis to bank-dependent firms in the United States that were not directly involved in the global financial market, as in Chava and Purnanandam (2006).

The importance of bank capital on bank lending has implications for the bank equity market. As argued by Bernanke and Lown (1991), imperfections in the market for bank equity can have distributional consequences. Some firms will be unable to obtain limited (and costly) bank loans. They will also be unable to get alternative funds from uninformed capital sources in the public debt and equity markets. Business investment may suffer as Table E indicates.



References

- Aikman, D and Vlieghe, G (2004)**, ‘How much does bank capital matter?’, *Bank of England Quarterly Bulletin*, Spring, pages 48-58.
- Alfon, I, Argimon, I and Bascuñana-Abrós, P (2004)**, ‘What determines how much capital is held by UK banks and building societies’, *Financial Services Authority Occasional Paper No. 22*, July.
- Arellano, M and Bover, O (1995)**, ‘Another look at the instrumental variable estimation of error-components models’, *Journal of Econometrics*, Vol. 68, pages 29-51.
- Aschraft, A (2005)**, ‘Are banks really special? New evidence from the FDIC-induced failure of healthy banks’, *American Economic Review*, Vol. 95, pages 1,712-30.
- Bank of England (1991)**, ‘Is there a ‘credit crunch?’’, *Bank of England Quarterly Bulletin*, Vol. 31, No. 2, pages 256–259.
- Bank of England (1993)**, ‘Banking Act Report 1992/3’, page 7.
- Bank of England (2005)**, *Financial Stability Review*, Issue 18, June.
- Berger, A N (1995)**, ‘The relationship between capital and earnings in banking’, *Journal of Money, Credit, and Banking*, Vol. 27, pages 432-56.
- Bernanke, B S (1983)**, ‘Nonmonetary effects of the financial crisis in the propagation of the Great Depression’, *American Economic Review*, Vol. 73, pages 257-76.
- Bernanke, B S and Lown, C S (1991)**, ‘The credit crunch’, *Brookings Papers on Economic Activity*, No. 2, pages 205-48.
- Bolton, P and Freixas, X (2006)**, ‘Corporate finance and the monetary transmission mechanism’, *Review of Financial Studies*, Vol. 19, pages 829-70.
- Caballero, R, Hoshi, T and Kashyap, A (2006)**, ‘Zombie lending and depressed restructuring in Japan’, *National Bureau of Economic Research Working Paper No. 12129*.
- Calomiris, C W and Wilson, B (2004)**, ‘Bank capital and portfolio management: the 1930s ‘capital crunch’ and the scramble to shed risk’, *Journal of Business*, Vol. 77, pages 421-55.
- Chava, S and Purnanandam, A (2006)**, ‘The effect of banking crisis on bank-dependent borrowers’, *mimeo*.



- Driscoll, J C (2004)**, ‘Does bank lending affect output? Evidence from the US states’, *Journal of Monetary Economics*, Vol. 51, pages 451-71.
- Ediz, T, Michael, I and Perraudin, W (1998)**, ‘The impact of capital requirements on UK bank behaviour’, *FRBNY Economic Policy Review*, October, pages 15-22.
- Ferri, G and Kang, T S (1999)**, ‘The credit channel at work: lessons from the Republic of Korea’s financial crisis’, *Economic Notes*, Vol. 28, pages 195-221.
- Financial Services Authority (2001)**, ‘Individual capital ratios for banks’, *Policy Statement*, July.
- Financial Services Authority (2006)**, ‘Distribution of UK incorporated banks’ individual capital ratios’, March.
- Fisher, I (1933)**, ‘The debt-deflation theory of great depressions’, *Econometrica*, Vol. 1, pages 337-57.
- Francis, W and Osborne, M (2009)**, ‘Bank regulation, capital and credit supply: measuring the impact of Prudential Standards’, *Financial Services Authority Occasional Paper 36*, September.
- Friedman, B (1991)**, ‘Comments and discussion’, *Brookings Papers on Economic Activity*, No. 2, pages 240-44.
- Gambacorta, L and Mistrulli, P E (2004)**, ‘Does bank capital affect lending behaviour?’, *Journal of Financial Intermediation*, Vol. 13, pages 436-57.
- Gan, J (2007)**, ‘The real effects of asset market bubbles: loan and firm-level evidence of a lending channel’, *Review of Financial Studies*, Vol. 20, pages 1,941-73.
- Gracie, A and Logan, A (2002)**, ‘UK bank exposures: data sources and financial stability analysis’, *Bank of England Financial Stability Review*, Issue 12, June, pages 105-15.
- Greenlaw, D, Hatzius, J, Kashyap, A and Shin, H S (2008)**, ‘Leveraged losses: lessons from the mortgage market meltdown’, *US Monetary Policy Forum Report*, No. 2.
- Haldane, A (2009)**, ‘Why banks failed the stress test’, Speech at the Marcus-Evans Conference on Stress-Testing.
- Hancock, D, Laing, A and Wilcox, J (1995)**, ‘Bank capital shocks: dynamic effects on securities, loans, and capital’, *Journal of Banking and Finance*, Vol. 19, pages 661-77.



Hancock, D, Peek J and Wilcox, J (2007), ‘The repercussions on small banks and small businesses of procyclical bank capital and countercyclical loan guarantees’, *mimeo*.

Holmstrom, B and Tirole, J (1997), ‘Financial intermediation, loanable funds, and the real sector’, *The Quarterly Journal of Economics*, Vol. 112, pages 663-91.

Hubbard, R G, Kuttner, K and Palia, D (2002), ‘Are there bank effects in borrowers’ costs of funds? Evidence from a matched sample of borrowers and banks’, *Journal of Business*, Vol. 75, pages 559-81.

Logan, A (2000), ‘The early 1990s small banks crisis: leading indicators’, *Bank of England Financial Stability Review*, Issue 9, December, pages 130-45.

Love, I (2001), ‘Estimating panel-data autoregressions, package of programs for Stata’, Columbia University, *mimeo*.

Love, I and Zicchino, L (2006), ‘Financial development and dynamic investment behaviour: evidence from panel vector autoregression’, *Quarterly Review of Economics and Finance*, Vol. 46, pages 190-210.

Markovic, B (2005), ‘Do bank capital buffers matter?’, University of Birmingham, *mimeo*.

Myers, S C and Majluf, N S (1984), ‘Corporate finance and investment decisions when firms have information that investors do not have’, *Journal of Financial Economics*, Vol. 13, pages 187-221.

Nier, E and Zicchino, L (2008), ‘Bank losses, monetary policy and financial stability - evidence on the interplay from panel data’, *IMF Working Paper No. 08/232*.

Peek, J and Rosengren, E S (1995), ‘The capital crunch: neither a borrower nor a lender be’, *Journal of Money, Credit, and Banking*, Vol. 27, pages 625-38.

Peek, J and Rosengren, E S (1997), ‘The international transmission of financial shocks: the case of Japan’, *American Economic Review*, Vol. 87, pages 495-505.

Peek, J and Rosengren, E S (2000), ‘Collateral damage: effects of the Japanese bank crisis on real activity in the United States’, *American Economic Review*, Vol. 90, pages 30-45.

Peek, J, Rosengren, E S and Tootell, G M B (2003), ‘Identifying the macroeconomic effect of loan supply shocks’, *Journal of Money, Credit, and Banking*, Vol. 35, pages 931-46.

Sims, C (1980), ‘Macroeconomics and reality’, *Econometrica*, Vol. 48, pages 1-49.



Stein, J C (2002), ‘Commentary’, *FRBNY Economic Policy Review*, May, pages 267-70.

Thakor, A (1996), ‘Capital requirements, monetary policy, and aggregate bank lending: theory and empirical evidence’, *Journal of Finance*, Vol. 51, pages 279-324.

Van den Heuvel, S J (2002), ‘Does bank capital matter for monetary transmission?’ *FRBNY Economic Policy Review*, May, pages 259-65.

Watanabe, W (2007), ‘Prudential regulation and the ‘capital crunch’: evidence from Japan’, *Journal of Money, Credit, and Banking*, Vol. 39, pages 639-65.

Woo, D (2003), ‘In search for ‘capital crunch’: supply factors behind the credit slowdown in Japan’, *Journal of Money, Credit, and Banking*, Vol. 35, pages 1,019-38.

