

# Bank regulation, capital and credit supply: Measuring the impact of Prudential Standards

**William Francis**  
**Matthew Osborne**  
UK Financial Services Authority\*

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The Financial Services Authority

25 The North Colonnade

Canary Wharf

London

E14 5HS

**Telephone: 020 7066 5808 or 3104**

**Email: [maria-jose.barbero@fsa.gov.uk](mailto:maria-jose.barbero@fsa.gov.uk) or [peter.andrews@fsa.gov.uk](mailto:peter.andrews@fsa.gov.uk)**

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## **Biographical note**

Matthew Osborne is an economist in the Economics of Financial Regulation (EFR) Department within the FSA's Strategy and Risk Division. William Francis has recently moved from EFR to the Board of Governors of the Federal Reserve System.

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## **Abstract**

The existence of a "bank capital channel", where shocks to a bank's capital affect the level and composition of its assets, implies that changes in bank capital regulation have implications for macroeconomic outcomes, since profit-maximising banks may respond by altering credit supply or making other changes to their asset mix. The existence of such a channel requires (i) that banks do not have excess capital with which to insulate credit supply from regulatory changes, (ii) raising capital is costly for banks, and (iii) firms and consumers in the economy are to some extent dependent on banks for credit. This study investigates evidence on the existence of a bank capital channel in the UK lending market. We estimate a long-run internal target risk-weighted capital ratio for each bank in the UK which is found to be a function of the capital requirements set for individual banks by the FSA and the Bank of England as the previous supervisor (Although within the FSA's regulatory capital framework the FSA's view of the capital that an individual bank should hold is given to the firm through individual capital guidance, for reasons of simplicity/consistency this paper refers throughout to "capital requirements"). We further find that in the period 1996-2007, banks with surpluses (deficits) of capital relative to this target tend to have higher (lower) growth in credit and other on- and off-balance sheet asset measures, and lower (higher) growth in regulatory capital and tier 1 capital. These findings have important implications for the assessment of changes to the design and calibration of capital requirements, since while tighter standards may produce significant benefits such as greater financial stability and a lower probability of crisis events, our results suggest that they may also have costs in terms of reduced loan supply. We find that a single percentage point increase in 2002 would have reduced lending by 1.2% and total risk weighted assets by 2.4% after four years. We also simulate the impact of a countercyclical capital requirement imposing three one-point rises in capital requirements in 1997, 2001 and 2003. By the end of 2007, these might have reduced the stock of lending by 5.2% and total risk-weighted assets by 10.2%.

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## **1 Introduction**

The recent market turmoil has highlighted the critical role that the banking industry plays in facilitating credit and economic growth. Indeed, this important link underlies the economic rationale for the stringent set of regulations imposed on the banking industry. These regulations include, among other things, formal capital requirements designed to force banks to internalize costs that they would not otherwise consider in their business practices and risk-taking behaviour. Such costs include the loss of sustainable output that can arise from widespread banking failures whether these are caused by overly optimistic, exuberant or inefficiently-priced lending or exogenous, unanticipated shocks to borrowers' creditworthiness.

Previous research shows that shocks to bank loan supply have dramatic effects on real activity. Bernanke (1983), for example, evaluated the causes of the Great Depression and found that the collapse of the financial system - more specifically, the failure of roughly half the banks in the US between 1930 and 1933 - explains a significant portion of the output loss suffered during that period.<sup>1</sup> Research by Bernanke and others supports the 'credit view' that financial intermediation - and in particular, the supply of loans by banks - is not perfectly substitutable for other funding and is therefore important for macro-economic activity.

Moreover, a large body of theoretical and empirical literature suggests that, contrary to the predictions of the Modigliani-Miller theorems (Modigliani and Miller (1958)), maintaining a higher capital ratio is costly for a bank and, consequently, a shortfall relative to the desired capital ratio may result in a downward shift in loan supply (Van den Heuvel (2004); Gambacorta and Mistrulli (2004)). For example, Adrian and Shin (2008) showed that, historically, banks have tended to adjust their balance sheets to attain a target level of leverage, and hence a negative shock to capital can lead to downward shifts in credit supply, resulting in procyclical effects of bank capital management.

Previous research also shows that regulatory tightening of capital ratios can produce analogous aggregate shocks and, therefore, that prudential capital requirements can influence macro-economic outcomes (see, for example, Bliss and Kaufman (2002)). The implication is that policymakers, in their design of capital regulation, and supervisors, in their review of capital adequacy plans or in setting bank-specific capital requirements under Pillar 2 of the Basel II rules, should ideally (i) consider the potential effects of capital requirements on financial stability and lending activity and (ii) assess the consequences for economic output. A well designed capital requirement would balance the costs that it imposes (e.g., loss of economic output due to slowdown in lending due to higher capital requirements) with the benefits it intends to deliver (e.g., reduction in the likelihood of financial crises and ensuing losses).<sup>2</sup> Undertaking this type of analysis, however, is difficult

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<sup>1</sup> This explanation is over and above that originally posited by the 'money view' of monetary policy. See, for example, Friedman and Schwartz (1963) for a discussion of this view. Friedman and Schwartz found a strong positive correlation between money supply and output, especially during the Great Depression, and attribute economic recessions to a decline in the money supply.

<sup>2</sup> See Barrell et al. (forthcoming).

without an understanding of how capital requirements affect bank behaviour and in particular, capital management and lending practices.<sup>3</sup>

Our paper examines the evidence for a 'bank capital channel' and focuses on providing measures of the effects of more stringent capital policies on bank lending and other measures of the scale of a bank's intermediation activity such as off-balance sheet assets (including credit commitments). Using a sample of almost 200 UK banking institutions for the period 1996 to 2007, we study the following questions: (i) Do regulatory capital requirements affect banks' target capital ratios? (ii) Does the level of a bank's capital relative to this target lead to adjustments in lending (or other asset categories) and/or capital growth?

The primary aim of our paper is to assess the effects of capital requirements on banks' internal capital targets and, in turn, lending behaviour. Our initial focus is on characterizing bank behaviour during periods of favourable economic conditions, since the emphasis of this study is on quantifying the impacts of countercyclical capital policies aimed at dampening potentially over-exuberant and damaging lending activity that may threaten long-run financial stability. Towards that objective, we employ data spanning the decade up to the start of the financial crisis in 2007 to describe bank capital management and lending behaviour in that period. Since it reflects a period of economic growth fuelled by what many have come to realize were overzealous underwriting practices, this baseline behaviour is precisely what countercyclical capital proposals currently under consideration aim to address.

A secondary aim of our paper is to use evidence of systematic association between changes in banks' balance sheets and banks' surplus or deficit relative to desired capital levels during economic upturns to develop measures that may assist policymakers in calibrating capital requirements, including proposals for counter-cyclical capital requirements, which are explicitly designed to address the build-up of risk during a credit boom. We do that by using our parameter estimates from our capital target and loan supply models to simulate the effects on loan growth of higher capital requirements during the period of strong economic growth leading up to the financial crisis. We recognize that results from these simulations offer only clues about how UK banks may respond to such measures during similar periods of rapid growth in the future.

We extend previous research on the effects of capital regulation on the capital management practices of banks in the UK (e.g., Alfon et al. (2004) and Francis and Osborne (2009)) to include explicit analysis of how banks adjust their balance sheets in order to manage the capital ratio. Previous researchers have found loan supply to be sensitive to a measure of internal capital adequacy (e.g., Hancock and Wilcox (1994), Nier and Zicchino (2005), Gambacorta and Mistrulli (2004) and Berrospide and Edge (2008)). In the majority of those studies, however, the desired or targeted capital levels are not conditioned on regulatory requirements, which could be used to test for such a 'regulatory effect'. Even in those where regulatory requirements are considered, the association between actual capital and regulatory capital requirements is not well established empirically (which may be explained

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<sup>3</sup> Capital requirements, if they restrict banks' ability to grant new loans, may limit the effectiveness of monetary policy aimed at ensuring sustainable economic growth over the long-term.

by a lack of variation in most countries of capital requirements across banks and over time). The absence of a clear correlation makes it difficult to assess how banks' capital management may respond to changes in capital requirements. Consequently, this disconnect makes it difficult to measure the impact of capital requirements on credit supply.

We extend the previous research by modelling banks' targeted capital ratios as a function of bank-specific, time-varying capital requirements set by regulatory authorities in the UK. We use the results to construct a time series of capital shortfalls (surpluses) for a panel of UK banks (where the measure equals the difference between actual and estimated target capital expressed as a proportion of targeted capital). We then use this variable in a panel regression of growth in lending and other asset-side components of the balance sheet, and also regulatory measures of capital. We also control for macroeconomic variables found useful in explaining loan growth in previous studies (e.g., Hancock and Wilcox (1994), Kashyap and Stein (1995, 2000) and Lown and Morgan (2006)). The coefficients from these capital and loan growth regression analyses allow us to isolate the influence of capital requirements on lending and capital management behaviour.

Our results show that regulatory capital requirements are positively associated with banks' targeted capital ratios. We further show that the gap between actual and targeted capital ratios is positively associated with banks' loan supply (suggesting that loan supply falls as actual capital falls below targeted levels), suggesting that banks amend their supply schedule (for example by raising the cost of borrowing or rationing credit supply at a given price) or take action to raise capital levels (for example, restricting dividends in order to retain profits or raising new equity or debt capital). Taken together, these results indicate that capital requirements affect credit supply, confirming the linkage found by previous researchers and demonstrating a 'credit view' channel through which prudential regulation affects economic output. We also find significant and positive relationships with growth in the size of banks' balance sheets and total risk-weighted assets, and significant and negative relationships with growth in capital.

The results provide a useful basis for measuring the effects of regulatory capital requirements on economic output and, importantly, a starting point for assessing proposals for revisions to the regime of capital regulation in the UK and worldwide. One policy proposal in particular has received a lot of attention and would involve the imposition of a countercyclical capital requirement that increases during benign economic periods and decrease during more trying times.<sup>4</sup> The objective of such a time-varying capital requirement is to reduce the severity and duration of economic downturns. This effect occurs directly through the 'bank capital channel' by altering a bank's cost of remunerating capital according to the state of the economy. The additional charges levied during more favourable economic conditions would raise the cost of lending, ostensibly slowing over-exuberant credit activity, which, as the recent market turmoil suggests, can be potentially damaging to financial stability and long-run economic output. While slowing economic

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<sup>4</sup> One prominent example of a proposal for a counter-cyclical capital requirement is in the FSA's Turner Review (FSA 2009). Our paper does not contribute to the debate about how counter-cyclical capital requirements should be calculated, but instead focuses on what the impact might have been during the years leading up to the crisis that started in 2007.

activity in the short-term, the additional capital required during the upturn would provide a cushion with which to absorb unexpected losses, allowing banks to sustain lending capacity during recessionary conditions. By effecting banks' ability to lend in this way, it is expected that the supply of bank credit will be less volatile, making large, prolonged business cycle fluctuations less likely.

The rest of this paper is arranged as follows. Section 2 provides background on capital and lending in the UK banking sector over the past two decades and reviews prior research on the bank capital channel and the impact of capital regulation on bank loan supply. We present a simple theoretical model of the bank's credit supply decision and outline testable implications in Section 3. In Section 4, we discuss our empirical model and the data. Section 5 reports empirical results, and Section 6 outlines policy implications including a simulation of an example counter-cyclical capital requirement. Section 7 concludes.

## **2 The bank capital channel and lending in the UK**

We review trends in real credit activity in the UK over the past twenty-five years to get an initial sense of periods of slowdown and, very broadly, the factors that may have contributed to these. Figure 1 reports credit activity as a percentage of GDP and the risk-weighted capital ratio of the UK banking sector<sup>5</sup> from the fourth quarter of 1989 to year end 2007.<sup>6</sup> The chart shows a clear slowdown in outstanding credit during the early part of the 1990's through 1996, after which credit supply picked up again. Credit activity then grew particularly rapidly between 2002 and 2008.

As mentioned above, the period 1990-1991 was marked by a notable decline in economic output, which may explain part of the drop in credit formation during that time. However, this period also saw a pronounced upward trend in banks' risk-weighted capital ratios,<sup>7</sup> possibly due to the introduction of the Basel I capital regime. Figure 1 suggests that in addition to deteriorating credit quality, regulatory pressure to raise capital levels may have dampened lending growth during the early part of the 1990's. An additional feature of these trends which backs this regulatory hypothesis is that the capital to (non-risk-weighted) assets ratio did not rise over the same period. Indeed, we note that a consistent trend during the period 1989-2007 was for the risk-weighted ratio to rise relative to the non-risk-weighted ratio, suggesting that banks may have altered their balance sheets over time to obtain more favourable treatment under the prevailing Basel I regulatory regime.

In contrast, from 1999 until 2007, we see a rapid expansion in credit activity as a percentage of GDP, coinciding with a reduction in the risk-weighted and non-risk-weighted

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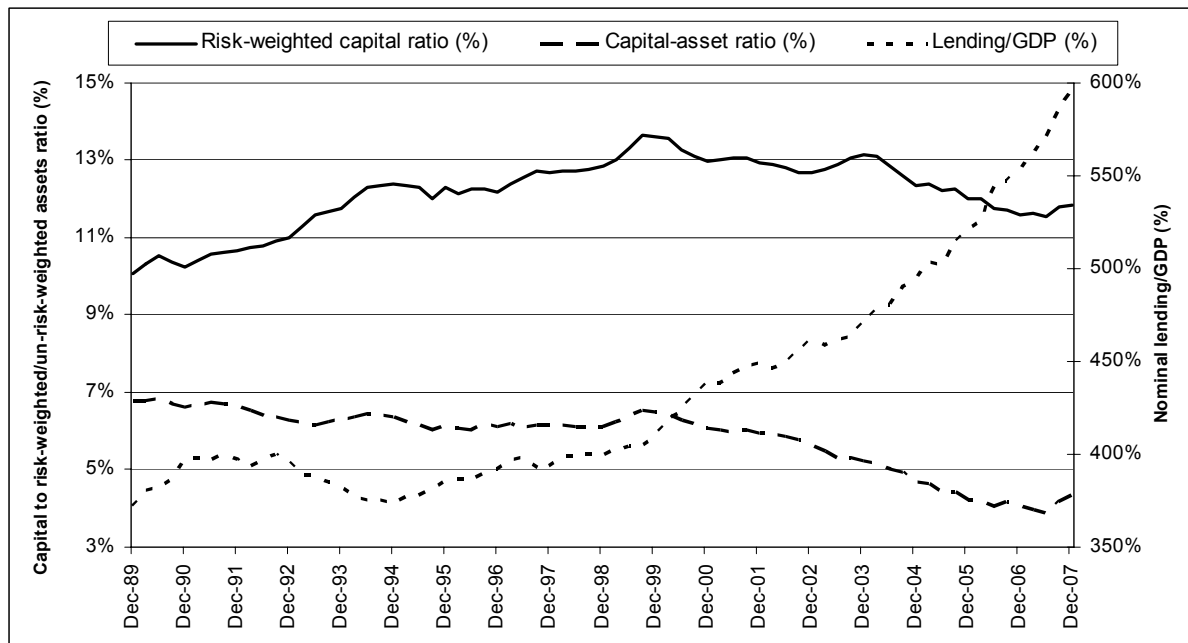
<sup>5</sup> Since Figure 1 shows only loans held on-balance sheet by banks, it may understate the expansion of credit in the period 1998-2007, when a large amount of lending was securitised and either held in off balance sheet vehicles or sold to investors. We also note that the risk-weighted capital ratio as shown may not capture the full extent of leverage in this period, since it does not include leverage embedded in complex structured credit products or certain off-balance sheet exposures (e.g., see Bank for International Settlements (2009)).

<sup>6</sup> Due to the transition to Basel 2 rules for capital adequacy, we do not show the numbers for 2008.

<sup>7</sup> The risk-weighted capital ratio is calculated as the ratio of regulatory capital over risk-weighted assets. Under Basel I a set of fixed risk-weights were applied to a bank's assets in order to capture likely losses across the portfolio. The capital ratio is calculated as the ratio of regulatory capital to total balance sheet assets.

capital ratios of UK banks. This suggests that lending growth may have been sustained by increases in the leverage of UK banks. Indeed, a credit boom fuelled by increased leverage has been cited by regulatory authorities as an important cause of the financial crisis that began in 2007.<sup>8</sup>

**Figure 1: Trends in lending and capital adequacy for the UK, 1989q4 to 2007q4**



Source: Financial Services Authority Banking Supervision Database and Bank of England

While these aggregate series point to some reasons for changes in credit activity observed over the past eighteen years, it is difficult to tell the extent to which these changes were supply- versus demand-driven and, more importantly, the degree to which they were attributable to changes in capital requirements. It is well known that bank lending decreases during periods of poor macroeconomic performance, which, in turn, affect bank capital. This drop, however, is at least partially due to an overall decline in investment activity or profitable lending opportunities and, thus, a downward shift in the demand for credit in general during these periods. Of interest to our research is to what extent banks' shifted their *supply* of loans during this time as a means of dealing with increased regulatory or market pressure on capital adequacy.

A contraction of credit supply during the early 1990s (and also during the distressed period of 2008-09) may be explained by the "bank capital channel" for the transmission of financial shocks into the real economy. Under the conditions that (i) banks do not have excess capital with which to sustain credit supply following a shock to the capital position (e.g., a tightening of capital regulation or monetary policy, or a decline in asset values), and (ii) there is an imperfect market for bank equity such that raising new capital is costly for banks, the financial structure of the bank affects the bank's supply of credit (Van den Heuvel (2004)). Hence, a bank may find it optimal, following an increase in regulatory capital standards, to reduce growth in risky assets, for example, by raising rates on lending,

<sup>8</sup> See FSA (2009), paragraph 3.6, and Bank for International Settlements (2008),

requiring higher collateral, or rationing credit at existing rates. This may lead to changes in macroeconomic outcomes if firms and consumers in the economy are to some extent dependent on bank credit.

Policymakers have long been interested in understanding the mechanisms that have the potential to change banks' lending behaviour and the role these play in affecting the economy more broadly. The large body of literature reviewing the 'bank lending channel' for the effects of monetary policy on the volume of credit in the economy is but one strand of research reflecting this widespread interest.<sup>9</sup> The impact of regulation on lending behaviour has also received a lot of attention by researchers, especially in response to the introduction of the Basel risk-based capital standards in the early 1990's.<sup>10</sup>

A primary focus of the literature on the 'bank capital channel' has been whether the introduction of risk-based capital requirements in the late 1980s and early 1990s caused banks to constrain credit supply, and whether this may have exacerbated the decline in economic activity in some countries. These studies have, in general, focused on the US, with only a limited number examining the evidence for other countries (or groups of countries). In one major effort based on US data, economists identified the introduction of the 1988 Basel Capital Accord as a possible explanation for the decline in lending in the US during the 1990-1991 recession. Using time-series, cross-sectional data on US banks, Berger and Udell (1994) examined whether the introduction of this more stringent regulatory capital regime contributed to the so-called 'credit crunch' that occurred in that country during the 1990-1991 recession. They find no support for this connection. In contrast, Peek and Rosengren (1995) find evidence, at least for banks in New England, that capital regulation (along with lower loan demand overall) contributed to the significant slowdown in credit activity during the 1990-1991 recession. Moreover, their results show that poorly capitalized banks reduced their lending more than their better-capitalized competitors. More mixed results were found by Hancock and Wilcox (1994), whose research showed that although banks which had a deficit of capital relative to the new risk-weighted capital standards tended to reduce their asset portfolios in the early 1990s, there was little evidence that the contraction was concentrated in highly risk-weighted assets as one would expect if the new regulation were driving the changes.

In a study using a cross-section of countries in a similar period, Wagster (1999) undertakes a similar analysis and fails to find support for a regulatory-capital-induced credit crunch in the cases of Germany, Japan, and the United States. He therefore confirms the results of Berger and Udell (1994) suggesting that a number of other factors, including a downturn in loan demand, contributed to the significant decline in credit activity after the introduction of the more stringent Basel I requirements. Interestingly, however, he finds some support for the notion that capital regulation may have contributed to a decrease in lending in Canada and the UK. In a similar study based on Latin American bank data, Barajas et al. (2005) find little evidence of a credit crunch induced by the introduction of the Basel Accord.<sup>11</sup>

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<sup>9</sup> See, for example, Bernanke and Blinder (1992), Bernanke and Gertler (1995), Thakor (1996), and Kashyap and Stein (1995, 2000).

<sup>10</sup> See, for example, Berger and Udell (1994), Hancock and Wilcox (1994) and Peek and Rosengren (1995).

<sup>11</sup> In a study based on banks in emerging markets, Hussain and Hassan (2006) find evidence that banks reduced credit risk as regulatory stringency (proxied by a shortfall of capital relative to regulatory mandates)

In a review of the literature on the impact of Basel I capital regulations, Jackson et al. (1999), conclude there is limited definitive evidence that capital regulation induced banks to maintain higher capital ratios than they would otherwise have held in the absence of regulation. This shortcoming is because most studies measure the regulatory effect by comparing the behaviour of banks which are near to the regulatory minimum with other banks not similarly constrained. Such comparison does not, however, permit the isolation of a regulatory effect, because it cannot disentangle regulatory pressure from market pressure to raise capital ratios when they are perceived as being too low. Unfortunately, due to a lack of variation in capital requirements between banks or over time, many more recent studies suffer from the same shortcoming (e.g., Stolz (2007); Blum and Nakane (2006); Memmel and Raupach (2007)).

These studies also do not explicitly examine whether banks responded to higher capital requirements by adjusting the numerator, i.e., capital, or the denominator, i.e., assets or risk weighted assets, of the capital ratio. As a result, they provide no firm empirical support for how banks responded to capital requirements and, in particular, how lending may have changed. Jackson et al. (1999), however, points out that most evidence suggests that at least in the short-term banks mainly respond to nearness to the regulatory minimum by reducing lending. In a more up-to-date review, VanHoose (2008) notes that almost all research on the microeconomic effects of bank capital regulation generates two common conclusions. First, the short-run effects of binding capital requirements are *reductions* in individual bank lending and, in analyses that include consideration of endogenous loan-market adjustments, *increases in equilibrium loan rates (or reduction in loan supply)*. Second, the *longer-run effects* of risk-based capital regulation lead to *increases in bank capital*, both absolutely and relative to bank lending. These effects are consistent with the 'bank capital channel' thesis.

In a unique approach to measure the impacts of capital regulation, Furfine (2001) develops a structural, dynamic model of a profit-maximizing banking firm to evaluate how banks adjust their loan portfolios over time with and without capital regulation. In his model, banks are exposed to costly regulatory intervention when they breach regulatory requirements. All banks, even those with excess capital, face this (expected) cost which lowers earnings and, ultimately, expected capital levels. While he does not strictly characterize it as such, this effect gives rise to a 'bank capital channel' in his framework. He uses actual data on US banking institutions to estimate the optimizing conditions directly. To get a sense for the impact on lending to changes in capital requirements, he then uses the estimated model to simulate the optimal bank responses. Based on simulation output, Furfine concludes that, although capital regulation matters, more stringent supervisory oversight that usually accompanies higher capital requirements generally has a larger effect on banks' balance sheet choices. The implication is that the reduction in lending observed in the US after the implementation of Basel I in the 1990's was likely attributable to the combined effects of tighter capital regulation and heightened supervision that accompanied the new regulation.

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increased. Findings are consistent with the idea that banks reduced the supply of risky lending (perhaps by shifting between risk classes) in response to increased capital requirements.

One notable study that addresses the problem of a lack of heterogeneity of capital requirements and assesses the impact on bank lending is Gambacorta and Mistrulli (2004). The authors explicitly examine the effects of the introduction of capital requirements higher than the Basel 8% solvency standard on lending volumes of Italian banks. They find that the imposition of higher requirements reduced lending by around 20% after two years. The results are consistent with the idea that, in the face of rising capital requirements, banks may find it less costly to adjust loans than capital as the risk-based capital requirement becomes increasingly more binding. Frictions in the market for bank capital make adjusting (raising) capital in response to higher regulatory requirements, in this case, expensive, so the result of the trade-off may be a reduction in lending. This result is consistent with the idea of a 'bank capital channel'.

One limitation with the literature surveyed here is that none of the papers examined explicitly include the impact of capital requirements on banks' internal capital ratio targets within their models of the determinants of lending supply. In this paper we seek to fill this gap by using data on the individual capital requirements that have been set by supervisors for each bank. This approach to setting capital requirements, which is similar to that adopted by many countries under Pillar 2 of Basel II, has been in place in the UK during the period in which Basel I was in effect and is over and above the minimum requirements specified in the Basel I agreement. Consequently, this regime provides a natural setting with which to evaluate the impact of a Pillar 2 type regime overall. In our sample period, individual capital requirements were set every 18-36 months, based on firm specific reviews and supervisory judgements about, among other things, evolving market conditions as well as the quality of risk management and banks' systems and controls. Previous studies over different time periods have found these individual capital requirements to be highly correlated with capital ratios after controlling for a host of other explanatory variables (Ediz et al. (1998); Alfon et al. (2004); Francis and Osborne (2009)), suggesting that banks tend to maintain a buffer over capital requirements, which varies in size depending on other bank-specific characteristics as well as macroeconomic conditions. It further suggests that even banks with large buffers may nonetheless be bound by regulatory capital requirements, in the sense that tighter standards will raise the probability of supervisory intervention and hence affect the bank's capital management. We develop this research further by estimating banks' internal capital targets as a function of capital requirements, calculating a measure of bank capitalization relative to this internal target which captures both regulatory and market measures of capital adequacy, and then analysing how banks adjust their capital and assets when their capital is above or below targeted levels.

### **3 A model of bank portfolio behaviour in the presence of capital requirements**

To set out some basic intuition on the effects of capital requirements on banks' capital and credit management practices, we develop a simple model of bank portfolio behaviour. Its main goal is to show how capital market imperfections at the bank level generate a lending channel of regulatory capital policy transmission. This section describes the model of optimal loan supply and its predictions about bank behaviour in response to changes in capital requirements.

The model has three time periods ( $t = 0, 1, 2$ ). This formulation allows us to evaluate the incentives, and consequent behaviours, of banks to maintain capital buffers (i.e., excess capitalization). At time 0, banks are endowed with initial capital of  $K_0^B$ . Capital evolves over time with the addition of retained profits,  $\pi_t$  (for  $t = 1$  and  $2$ ), as well as the issuance (redemption) of new (existing) capital,  $K_t^E$  (for  $t = 0$  and  $1$ ). Due to informational problems that accompany new capital issues and redemptions (see, for example, Myers and Majluf (1984)), it is costly for banks to adjust capital. At time  $t = 2$ , banks are liquidated, with shareholders receiving capital and earnings (described in more detail below) retained during periods 1 and 2.

In each period, the bank's asset portfolio consists of loans ( $L$ ) and government securities ( $G$ ), which differ according to their risk-return profiles. The market for loans is assumed to be imperfectly elastic, which affords the bank some power to set the rates on loans in response to its own optimizing behaviour. We assume that the quantity of loans (demand) is inversely related to bank's offered rate,

$$L = L(r_L), \quad L'(r_L) < 0. \tag{1}$$

Loans are assumed to be inherently more risky and, therefore, provide a higher rate of return  $r_L$  compared with government securities. Banks make loans at time 0; however, once originated, loans cannot be liquidated until the end of period 2 (i.e., at time  $t = 2$ ). While this framework is more extreme than in practice, our main interest is in capturing the fact that banks face uncertainty with respect to capital requirements on loans at time of origination. Somewhat consistent with this idea, other researchers have noted that banks also face liquidity risk and costs in liquidating loans early.<sup>12</sup>

At time 0, banks can also invest an amount  $G$  in government securities, e.g., government gilts. Because they pose less credit risk versus loans, such securities yield a return of  $r_G$ , lower than  $r_L$ . There are a couple other key differences between loans and government securities that are important to our model. First, government securities can be liquidated at no cost at time 1. In that regard, they provide a secondary source of liquidity to banks and thus present less liquidity risk compared with loans. Second, because they are inherently less risky (both in terms of credit and liquidity risk), government securities attract a lower regulatory risk weighting compared with loans and, as a result, a lower regulatory capital charge (discussed below). For simplicity, we assume that the risk weighting and, therefore, the corresponding capital requirement on government securities are zero. As will become clear, it is because of these features that banks will in equilibrium elect to hold securities even when they offer a lower return versus loans, i.e., even when  $r_L > r_G$ .

Banks support their asset portfolios with funding from two sources: demand deposits ( $D$ ) and equity capital ( $K$ ). At time 0, deposits are  $D_0$ , and at time 1, they are  $D_1$ . We assume

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<sup>12</sup> In particular, loans represent an additional liquidity risk to the bank to the extent that depositors demand their funds at time 1. See, for example, Diamond and Dybvig (1983) for the basis for this assumption.

that  $D_0$  and  $D_1$  are out of control of individual banks and are determined by central bank monetary policy. Contractionary monetary policy actions at time 1 create a net deposit funding shock for the typical bank in our framework. We recognize that this description is with respect to the aggregate amount of deposits. It does not mean that monetary policy can directly control the deposits of any given individual bank. If banks can compete by offering higher rates or improving the quality of their service on such deposits, then they may be able to mitigate the effect of monetary policy on their deposit base. We also, for the sake of keeping things simple, abstract from the possibility that banks may be able to tap other funding sources (e.g., inter-bank borrowings) to offset erosion to deposits in response to monetary policy. Even if we were to introduce competition in the market for (uninsured) funding, the costs to banks of attracting such funding may also depend on bank capitalization (due to informational asymmetries between banks and suppliers of funds).<sup>13</sup>

Demand deposits cost  $r_d$  ( $< r_g < r_l$ ) and carry mandatory reserve requirements equal to  $gD$ , where  $g$  represents a fraction ( $\in (0,1)$ ) of the deposit balance. In our setup, banks can use government securities to satisfy this requirement, implying that they must hold government securities greater than or equal to  $gD$ .<sup>14</sup> For our purposes, we normalize the returns on deposits to be zero. Therefore, the yields on loans,  $r_l$ , and government securities,  $r_g$ , in our framework really measure the spreads on these two assets.

We assume, as another simplification, that deposit withdrawals are deterministic and therefore that a bank's reserves,  $gD$ , are sufficient to satisfy depositor demands. We do this because we are primarily interested in highlighting how direct shocks to a bank's capital affect its lending and capital management practices. While we acknowledge that a stochastic deposit base can produce indirect shocks on bank capital (e.g., through the effect that uncertain deposit supply may have on a bank's profits and, in particular, the need to borrow from other sources at higher rates), and may be more realistic, it adds unnecessary complexity to the model at this stage.<sup>15</sup>

Banks are subject to regulatory capital requirements similar in spirit to those under the Basel Capital Accord. That is, in our formulation banks are required to hold capital equal to  $K_t^R = k_{R,t}L$  (for  $t = 0$  and  $1$ ), where  $K_t^R$  is the requisite *level* of regulatory capital at time  $t$  and  $k_{R,t}$  is a percentage ( $\in (0,100)$ ) set by the regulator based on its assessment of bank-specific loan portfolio risk at time  $t$ . The requirement,  $k_{R,t}$ , consists of two elements. The first is a rule-based, non-discretionary minimum proportion known to bankers at all times. We call this the minimum requirement and denote it as  $k_{R,t}^{Min}$ . The second is a discretionary proportion set by the regulator based on its evaluation of bank-specific risk. These assessments can change over time and reflect, among other things, supervisory views about the risk profile of an institutions loan portfolio, the quality of management and systems and controls over the loan portfolio, as well as the contribution of a bank's risk to the overall risk of the industry (based on proprietary knowledge held by the supervisor). In that regard, the capital requirement is not perfectly known by the bank when it sets its

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<sup>13</sup> By capitalization we mean how a bank's actual capital compares with its regulatory minimum.

<sup>14</sup> Note that such reserves represent an additional cost of demand deposit funding since the fractional reserve requirement cannot be used to support higher yielding loans.

<sup>15</sup> We plan to pursue this issue in future research.

lending rates (and loan volume). We denote the random portion of the capital requirement as  $\tilde{k}_{R,t}^{Disc}$ . Using these definitions, we can express the overall regulatory capital requirement as  $K_t^R = (k_{R,t}^{Min} + \tilde{k}_{R,t}^{Disc})L$  (for  $t = 0$  and  $1$ ).

Under this framework, then, the capital requirement is partially out of control of (and unknown to) individual banks and limits the extent to which a bank can employ deposits to support (and grow) its asset portfolio. That is, at time 0, time 1 regulatory capital requirements are not known with certainty. As a result, banks must base their initial offered loan rates on their expectations about capital requirements and the attendant capital compliance costs. At time 0, banks know the regulatory capital requirement and, therefore, the amount of capital they must hold for their chosen loan supply,  $L$ . But, because they cannot liquidate these loans at time 1, they face possible capital compliance costs associated with these loans to the extent that the discretionary portion of the regulatory requirement changes over time. It is this aspect of the regulatory requirement that impacts loan supply and motivates banks to hold capital buffers at time 0. By imposing higher (discretionary) requirements at time 1, a regulator effectively produces a capital shock, reducing a bank's overall lending capacity (and raising expected capital compliance costs).

Our main focus below will be on illustrating the effect of a change in expected time 1 capital requirements on a bank's loan supply and capital management decisions. This effect will depend on how a bank's capital level at time 1 (i.e., at the beginning of period 2)  $K_1^B$ , which evolves as the sum of the initial capital endowment and profits retained over the period, i.e.,  $K_0^B + \pi_1$ , compares with regulatory capital minimums set at that time,  $K_t^R = (k_{R,t}^{Min} + \tilde{k}_{R,t}^{Disc})L$ , for  $t = 0$  and  $1$ . How might a bank respond to an exogenous shock to its capitalization due to, say, higher capital requirements ( $k_{R,t} = (k_{R,t}^{Min} + \tilde{k}_{R,t}^{Disc})$  for  $t = 1$ ) set by a regulator? Essentially, it can respond in three ways: (i) it can cut back on the loans it makes (at time 0); (ii) it can sell other assets (e.g., government securities); or (iii) it can attempt to raise additional capital. For capital regulation to be effective in altering loan supply, it must be that the bank desires to do some of the adjustment by reducing loans (i.e., originating a smaller amount at time 0). Stated differently, it must be the case that the bank cannot costlessly adjust capital to insulate its loan supply from regulatory policy shocks. This condition implies that the market for bank capital is not frictionless (and that the Modigliani-Miller propositions do not hold for banks). The Myers and Majluf (1984) market imperfections alluded to earlier suggest an increasing marginal cost of raising additional capital, which explains why option (iii) cannot be used to insulate lending supply completely from regulatory shocks.

As mentioned, capital evolves over time as the cumulative sum of the initial capital endowment and profits earned over time. This amount can, at the bank's discretion, be supplemented (reduced) by capital issuances (redemptions). We denote capital at time  $t = 1$  capital (i.e., the beginning of period 2), as the initial endowment plus any profits accrued during the first period and capital raised at time 1, i.e.,  $K_1^B = K_0^B + \pi_1 + K_1^E$ .<sup>16</sup> The

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<sup>16</sup> In principle,  $K_1^E$  could be negative, representing a dividend payout or equity redemption, at time 1.

framework captures the idea, then, that if a regulator introduces higher capital requirements, banks have the option of raising capital and that they are not limited only to reducing loans to meet the new mandates. Our model depends on the assumptions that we make about the costs of adjusting capital. We assume that these costs are quadratic (because of the imperfections noted earlier and the increasing marginal costs they imply) and that the costs at time 1 are given by  $\beta_1(K_1^E)^2/2$ . It is important to note that the specific functional form is not critical, but that the presence of increasing marginal costs of adjusting capital is.

In the extreme case where  $\beta_1 = 0$ , adjusting capital is costless and therefore banks can, in response to higher capital requirements, raise the necessary capital to shield loan supply. This notion is consistent with the Modigliani-Miller (1958) propositions on capital irrelevance. As will be shown below, this assumption will completely negate the ability of capital regulation to alter bank lending.

Our hypothesis is that this assumption is likely to be unrealistic. Indeed, empirical research suggests that while banks may alter their capital in response to changes in capital requirements, the adjustments are not one for one, implying that there may, in fact, be other cost considerations involved. As a result, we assume that the Modigliani-Miller propositions do not hold, and that there are imperfections in the market for equity capital.<sup>17</sup> This notion is not unreasonable, since if there is some degree of asymmetric information between the bank and investors, the typical adverse selection problems (see, for example, Myers and Majluf (1984), Stein (1998) and Cornett and Tehranian (1994)) will arise. These frictions will generally make the marginal cost of raising capital an increasing function of the amount issued, hence our use of the quadratic cost function introduced earlier.<sup>18</sup>

Using these basic assumptions, we characterize a bank's portfolio choice problem at times 0 and 1. To simplify matters, we work backwards from time 2. The bank enters this period with loans of  $L$ , securities of  $G$  and a capital cushion of  $K_0^E (= K_0^B - k_{R,0}L)$  already on the balance sheet. At time 1, regulators reassess the bank's risk and update capital requirements of  $K_1^R = k_{R,1}L$ , where  $k_{R,1} = (k_R^{Min} + \tilde{k}_{R,1}^{Disc})$  is not necessarily equal to  $k_{R,0} = (k_R^{Min} + \tilde{k}_{R,0}^{Disc})$  because of the discretion afforded regulators in setting additional capital requirements over and above minimums. Again, it is the uncertainty around the regulator's assessment (and therefore regulatory capital compliance costs) that provides banks with incentives to hold excess capital at time 0. Because only the minimum capital requirement is known by the bank, the bank is uncertain about the overall capital charge (and expected capital compliance costs) when it makes its initial loan supply decision (at time 0). The time 1 value of capital,  $K_1^B = k_{R,0}L + K_0^E + \pi_1$  is realized at the beginning of time 2 (i.e., at time  $t = 1$ ). We distinguish between two unique cases:

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<sup>17</sup> See Berger, for example, et al. (1995) and Stolz (2007) for useful summaries of real-world deviations from the Modigliani-Miller capital irrelevance propositions.

<sup>18</sup> It may also seem reasonable to suspect that the sensitivity of these costs, as reflected in the parameter  $\beta_1$  may differ according to the financial characteristics of the bank.

**Case 1:**  $K_1^B = k_{R,0}L + K_0^E + \pi_1 > K_1^R = k_{R,1}L$  In this case the bank can continue to meet its capital requirement and support its lending activities without having to raise new capital at time 1 (i.e., the beginning of time 2).

**Case 2:**  $K_1^B = k_{R,0}L + K_0^E + \pi_1 < K_1^R = k_{R,1}L$  In this case the bank finds itself short of capital at time 1 (i.e., the beginning of time 2) and must raise additional capital of  $K_1^E = k_{R,1}L - [k_{R,0}L + K_0^E + \pi_1]$  to support its lending activity. The net result is that the extra capital needed in the event of a shortfall can be expressed as:

$$K_1^E = \text{Max}\{0, k_{R,1}L - [k_{R,0}L + K_0^E + \pi_1]\} \quad (2)$$

The costs associated with this amount of capital are given by  $\beta_1(K_1^E)^2 / 2$ , where  $\beta_1$  represents per unit cost of capital and  $K_1^E$  represents the amount by which time 1 capital requirements exceed actual capital levels held by the bank at time 1. Put another way,  $K_1^E$  is the amount of capital shortfall that the bank must raise to satisfy the regulatory requirements at time 1. The ex ante expectation of time 1 capital compliance costs at time 0 is given by the probability of a capital shortfall (i.e., breaching its regulatory requirement) at time 1 (the beginning of time 2), i.e.,  $\Pr(K_1^B = k_{R,0}L + K_0^E + \pi_1 < K_1^R = (k_{R,1}^{Min} + \tilde{k}_{R,1}^{Disc})L)$ ,<sup>19</sup> multiplied by the shortfall, all squared, then multiplied by the per unit cost,  $\beta_1$ , divided by two. Letting the probability of a capital shortfall equal  $P_s$ , we can express the expected capital adjustment costs as:

$$\text{Expectation} [\beta_1(K_1^E)^2 / 2] = \beta_1 P_s [(k_{R,0}L + K_0^E + \pi_1) - (k_{R,1}^{Min} + \tilde{k}_{R,1}^{Disc})L]^2 / 2. \quad (3)$$

Using (3) allows us to express the time 0 optimization problem. At time 0, the bank chooses  $r_L$  (and implicitly  $K_0^E = K_0^B - k_{R,0}L$  and  $G = D_0 + K_0^B - L$ ) to maximize the value of the firm. Formally, this problem can be expressed as:

$$\text{Max}_{r_L} E[V] = r_L L + r_G G + \beta_1 (E[K_1^E])^2 / 2, \quad (4)$$

which upon substituting (3) into (4) yields:

$$\text{Max}_{r_L} E[V] = r_L L + r_G G + \beta_1 P_s [k_{R,0}L + K_0^E + \pi_1 - (k_{R,1}^{Min} + \tilde{k}_{R,1}^{Disc})L]^2 / 2. \quad (5)$$

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<sup>19</sup> This is equivalent to the probability that  $K_1^E > 0$ .

The last term in (5) provides a measure of the expected total costs of adjusting capital to meet new capital requirements set at time 1.<sup>20</sup> The first-order condition for the bank decision variable, loan rate, is

$$\frac{dV}{dr_L} = L + r_L L' - r_G L' + \beta_1 P_S K_1^E [L'(k_{R,0} - k_{R,1}) + L + r_L L' - r_G L'] = 0, \quad (6)$$

where  $L' = dL/dr_L < 0$ . We also assume that at the optimal solution,  $r_L^*$ , the second-order (sufficient) condition for maximization is satisfied, i.e.,  $d^2V/dr_L^2 < 0$ . Further rearrangement yields the optimizing conditions:

$$L + r_L L' - r_G L' = -\beta_1 P_S K_1^E [L'(k_{R,0} - k_{R,1}) + L + r_L L' - r_G L']. \quad (7)$$

The terms on the left-hand side represent the marginal profit arising from a change in the loan rate. The right-hand side is the expected capital adjustment cost multiplied by the impact of a change in the lending rate on the capital constraint at time 1. The bank sets its loan rate (i.e., its decision variable) such that it equates the marginal profit from that variable with the marginal costs, with the marginal costs now including the marginal adjustment costs that arise in filling any capital shortfall demanded by the regulatory capital constraint.

The implication of this result is that, everything else equal, banks must increase marginal profit in the loan market to equal higher expected capital adjustment costs, which, in turn, requires an increase in loan rates and lowers expected lending. The comparative statics effect of a change in capital requirements on the loan rate further suggests this behaviour. Using (6) and the implicit function theorem, we can formally evaluate the change in capital requirements on the loan rate as follows:

$$\frac{dr_L}{dk_{R,1}} = -\frac{\frac{\partial}{\partial k_{R,1}} \{L + r_L L' - r_G L' + \beta_1 P_S K_1^E [L'(k_{R,0} - k_{R,1}) + L + r_L L' + r_G L']\}}{\frac{\partial}{\partial r_L} \{L + r_L L' - r_G L' + \beta_1 P_S K_1^E [L'(k_{R,0} - k_{R,1}) + L + r_L L' + r_G L']\}} > 0. \quad (8)$$

This expression is positive since the denominator is negative (by the second-order condition,  $d^2V/dr_L^2 < 0$ ) and the numerator is positive.<sup>21</sup> As a result, higher expected time

<sup>20</sup> Technically, this value depends on the density of the random discretionary component of the regulatory capital requirement,  $f(\tilde{k}_{R,1}^{Disc})$ . Letting  $q(r_L)$  denote the capital evolution function ( $q(r_L) = K_0^B + r_L L + r_G G$ ), the expected total cost of a capital shortfall can be expressed as  $\beta_1 \int_{q(r_L)}^{\infty} \frac{1}{2} [q(r_L) - (k_R^{Min} + \tilde{k}_R^{Disc})L]^2 f(\tilde{k}_R^{Disc}) d\tilde{k}_R^{Disc}$ .

1 capital requirement implies that expected marginal profit is raised by setting a higher loan rate which results in a lower level of expected loans.

In a similar way, the comparative statics effect of a change in the per unit capital adjustment cost on the loan rate is

$$\frac{dr_L}{d\beta_1} = - \frac{\frac{\partial}{\partial \beta_1} \{L + r_L L' - r_G L' + \beta_1 P_S K_1^E [L'(k_{R,0} - k_{R,1}) + L + r_L L' + r_G L']\}}{\frac{\partial}{\partial k_{R,1}} \{L + r_L L' - r_G L' + \beta_1 P_S K_1^E [L'(k_{R,0} - k_{R,1}) + L + r_L L' + r_G L']\}} > 0, \quad (9)$$

which is also positive by the fact that the denominator is negative (by the second-order condition) and the numerator positive. The implication of this result is that higher per unit capital adjustment costs means an increase in loan rates and decrease in expected loans overall.

The comparative statics explicitly set out the 'bank capital channel' which shows how lending depends on the bank's capital structure (cushion) and profitability. They also show that the lower the cost of adjusting capital or the likelihood of suffering a capital shortfall, the lower the optimal loan rate (and greater a bank's optimal loan supply). In the limit when either is equal to zero, any positive value of the loan-deposit spread results in an infinite loan supply. Importantly, the expressions show that capital requirements dampen these effects, i.e., loan supply is negatively influenced by higher expected capital requirements.

Using the balance sheet identity and the definition of capital buffers, we can extend the findings from (8) to make statements about how higher expected capital requirements feed through to impact capital buffers ( $K_0^E$ ) and balance sheet make-up ( $L$  and  $G$ ) at time 0. Recalling that loans are a function of the lending rate, we can express the capital buffer at time 0 as

$$K_0^{E*} = K_0^R - k_{R,0} L(r_L^*). \quad (10)$$

The comparative statics effect in (8) suggests that the optimal time 0 capital buffer increases given an increase in expected time 1 capital requirements.<sup>22</sup> This result derives from taking the partial derivative of  $K_0^E$  with respect to time 1 capital requirements:

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<sup>21</sup> The positive sign can be seen by looking in more detail at the components and signs of this derivative:

$\frac{\partial}{\partial k_{R,1}} \{L + r_L L' - r_G L' + \beta_1 P_S K_1^E [L'(k_{R,0} - k_{R,1}) + L + r_L L' + r_G L']\} = -\beta_1 P_S K_1^E [L' k_{R,1}]$ . And since

$L' = dL/dr_L < 0$ , the expression is positive.

<sup>22</sup> This result derives from taking the partial derivative of (10) with respect to time 1 capital requirements.

$$\frac{\partial K_0^{E*}}{\partial k_{R,1}} = -k_{R,0} \frac{dL}{dr_L^*} \frac{dr_L^*}{dk_{R,1}} > 0. \quad (11)$$

The result shows that the optimal capital buffer held at time 0 increases as expected time 1 capital requirements increase. This result also shows that the magnitude of the effect of time 1 capital requirements on optimal capital buffers depends on the elasticity of the bank's loan market.

In a similar way, we can evaluate the impact of higher per unit capital adjustment costs on optimal capital buffers. Extending (9), the comparative statics effect is as follows:

$$\frac{\partial K_0^{E*}}{\partial \beta_1} = -k_{R,0} \frac{dL}{dr_L^*} \frac{dr_L^*}{d\beta_1} > 0. \quad (12)$$

This result suggests that higher per unit capital adjustment costs lead banks to raise loan rates and, in turn, hold higher initial capital buffers as a way to mitigate costly regulatory capital breaches.

The balance sheet identity,  $L + G = D_0 + K_0^B$ , together with the comparative statics in above imply that optimal time 0 government securities holdings are affected by expected time 1 capital requirements and per unit adjustment costs in a similar way. That is,

$$\frac{\partial G_0^*}{\partial k_{R,1}} = -\frac{dL}{dr_L^*} \frac{dr_L^*}{dk_{R,1}} > 0, \quad (13)$$

and

$$\frac{\partial G_0^*}{\partial \beta_1} = -\frac{dL}{dr_L^*} \frac{dr_L^*}{d\beta_1} > 0. \quad (14)$$

Both suggest that banks will optimally elect to hold more government securities, which carry lower capital charges compared with loans, as expected time 1 capital requirements increase or per unit capital adjustment costs rise.

The model presented in this section provides a basic understanding of how capital requirements affect a bank's optimal capital and lending behaviour when it faces increasing marginal costs of adjusting capital. It characterizes how, in the presences of imperfections in the market for bank capital, a 'bank capital channel' can arise through which regulation effects lending. Results suggest that optimal loan rates and capital buffers are positively

related with expected capital requirements and per unit capital adjustment costs. This relationship implies lower overall expected lending. Banks also elect to originate fewer loans when they perceive that there is a greater chance of suffering a capital shortfall and, therefore, incurring costs of raising new capital. In this case, they will tend to hold more government securities as a way of lowering capital requirements and the expected costs of resolving a capital shortfall. These conditions imply a breakdown of the Modigliani-Miller propositions for banks with lending depending on a bank's desired capital structure.

This model provides a fundamental understanding of the effects of capital requirements on a bank's capital and lending management practices. Its main implications are that capital requirements (i) affect banks' incentives to hold capital buffers, (ii) affect banks' incentives and ability to lend, and (iii) affect banks' incentives to substitute away from loans and into risk-free assets. As discussed, its predictions depend in large part on departures from the Modigliani-Miller propositions, the presence of market frictions and increasing marginal costs of capital adjustment.

## **4 Estimating the effects of capital requirements on bank capital and lending**

The theoretical model in the previous section shows how the link between lending and capital requirements may arise. In particular, the link stems from banks' desire to avoid costly capital adjustments and regulatory interventions. As shown, the strength of that association depends on the probability of a capital shortfall (e.g., relative to regulatory thresholds) and the marginal costs of adjusting capital. In this section, we develop proxies for these factors and describe how we estimate the effects of regulatory capital requirements on banks' capital and lending activity. It also discusses how we address various estimation issues that occur when dealing with panel data.

Very briefly, our approach involves three steps. First, we specify and estimate a partial adjustment model of bank capital that depends on bank-specific features, including individual capital requirements assigned by the FSA. This step is justified by theory and empirical evidence supporting the idea that banks manage their capital to meet a desired, or long-run, target that depends significantly on capital requirements. Second, we use the parameters from this model to derive each bank's (unobservable) target capital and an index of a bank's capitalization (i.e., surplus or deficit) relative to its target. Finally, we use this measure of bank capitalization to estimate models of balance sheet, lending and capital growth.

### **4.1 Estimating the target capital ratio for each bank**

This subsection discusses the approach we took to estimate the target capital ratios for each bank in our sample. It outlines the measures used to control for potential heterogeneity in banks' incentives and abilities to amend their capital ratios and the methods we used to overcome issues when using panel data. Finally, it describes the measure of bank capitalization and its underlying computation.

We model each bank's target risk-weighted capital ratio ( $k_{i,t}^*$ ) as a function of a vector of  $N$  bank- and time-specific characteristics ( $X_{n,i,t}$ ), and a fixed effect ( $\eta_i$ ) for each bank which captures idiosyncratic factors such as business model, management, risk aversion and the mix of markets in which the bank operates. This specification takes the following form:

$$k_{i,t}^* = \eta_i + \sum_{n=1}^N \theta_n \cdot X_{n,i,t}. \quad (1)$$

We assume that banks take time to adjust their capital and assets towards their target capital ratio, and we model this as a partial adjustment process following Berrospide and Edge (2008) and Hancock and Wilcox (1994). This approach is based on the idea that capital adjustment costs preclude banks from achieving their desired levels immediately. As a result, the change in the capital ratio in each period is a function of the gap between the target and actual capital ratio in the previous period:

$$k_{i,t} - k_{i,t-1} = \lambda(k_{i,t-1}^* - k_{i,t-1}) + \varepsilon_{i,t}, \quad (2)$$

where  $k_{i,t}$  ( $k_{i,t-1}^*$ ) is the actual (optimum) capital ratio of bank  $i$  at time  $t$  ( $t-1$ ),  $\lambda$  is the speed of adjustment, and  $\varepsilon_{i,t}$  is the error term. Substituting (1) into (2) and rearranging gives us our primary estimation equation:

$$k_{i,t} = (1 - \lambda) \cdot k_{i,t-1} + \lambda(\eta_i + \sum_{n=1}^N \theta_n \cdot X_{n,i,t-1}) + \varepsilon_{i,t}. \quad (3)$$

We derive the long-run parameters,  $\eta_i$  and  $\theta_n$ , from the results of estimating (3), taking into account the implied value of the adjustment speed. In practice, in order to capture the full effect of each of the  $N$  explanatory variables, we estimate (3) using two lags of each of these ( $t-1$  and  $t-2$ ) and also two lags of the dependent variable. Thus we estimate

$$k_{i,t} = a_0 + \sum_{j=1,2} a_{1,j} \cdot k_{i,t-j} + \sum_{n=1}^N \sum_{j=1,2} b_{n,j} \cdot X_{n,i,t-j} + \varepsilon_{i,t}.$$

The long run effect of each explanatory variable is given by:

$$\theta_n = \frac{\sum_{j=1,2} b_{n,t-j}}{1 - \sum_{j=1,2} a_{t-j}}$$

Following previous work in Francis and Osborne (2009), we include a wide range of bank-specific variables in equation (3). Our main variable of interest is the individual (bank-specific) capital requirement set by FSA supervisors, which is expressed as a required percentage of capital over risk-weighted assets. This requirement will always be equal to or greater than the Basel minimum of 8% and reflects supervisory judgments about risks not captured in the Basel capital framework and considers other factors, including the quality of bank management, corporate governance and systems and controls. In practice, different

capital requirements may be applied to a bank's banking and trading books, so we use the overall required ratio, calculated as a weighted average.

We include a number of other variables to control for systematic differences in banks' ability and incentives to adjust capital and which have been found useful in the literature on the determinants of bank capital ratios.<sup>23</sup> One likely determinant of a bank's desired capital ratio is the expected cost of failure, which depends on the likelihood and cost of failure. The risk-weighted capital ratio already includes a regulatory measure of risk embedded within it, but we include the ratio of risk-weighted assets, as defined under Basel I, to total assets (RISK), to assess whether the relationship between capital and risk may be non-linear (e.g. riskier banks hold less capital against a given risk-asset due to better systems and controls or risk preferences). Since this can be thought of as a regulatory measure of risk, we also include the ratio of total provisions over on-balance-sheet assets as a proxy for each bank's own internal estimate of risk (PROVISIONS). PROVISIONS reflect management's assessment of the losses embedded in the bank's asset portfolio. We control for the degree to which a bank is exposed to market discipline by including the ratio of subordinated term debt to total liabilities (SUBDEBT), since there is evidence that subordinated debtholders may be effective in imposing discipline on bank behaviour (see, for example, Covitz et al. (2004)). Since the composition of a bank's capital base may affect the capacity to absorb losses, which may affect the market's perception of the riskiness of the bank, we include the ratio of tier 1 over total capital as a proxy for the quality of capital (TIER1). We also include a proxy for bank size (SIZE), calculated by taking the time demeaned value of the log of total assets,<sup>24</sup> as previous studies argue that larger banks may be better able to diversify risks, access funding and adjust capital compared with smaller institutions. To proxy the cost of capital, we include annualized return on equity<sup>25</sup> (ROE). Finally, to control for different business models in banks with large trading portfolios, we include the ratio of trading book assets to total balance sheet assets (TRADE).

## 4.2 Calculation of bank capitalization

We calculate a target capital *ratio* for each bank using the long-run parameters in equation (1) (as derived from parameters on the vector  $X_{n,i,t}$  estimated in equation (3)). We follow Hancock and Wilcox (1993; 1994) and derive the target *level* of capital at time t by multiplying the target capital ratio by total risk-weighted assets at time t-1. Then, we calculate the banks surplus or deficit relative to this target level of capital as:

$$Z_{i,t}^1 = 100 * \left( \frac{K_{i,t-1}}{K_{i,t}^*} - 1 \right) , \quad (4)$$

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<sup>23</sup> A review of literature on the determinants of bank capital ratios can be found in Francis and Osborne (2009).

<sup>24</sup> Time demeaning is carried out by calculating the mean log of total assets across all banks in each time period, and then subtracting this from each banks' log of total assets in each time period. We do this to avoid spurious correlation between total assets and capital ratios resulting from non-stationarity.

<sup>25</sup> We note that ROE is not a perfect measure since it will capture factors other than the cost of capital, such as the degree of competition and macroeconomic conditions. However, it was the only variable available to us.

where  $K_{i,t}^*$  is defined as  $K_{i,t}^* = k_{i,t}^* * rwa_{i,t-1}$ , and represents the bank's level of capital at time t required to achieve target capital ratio at time t, given the risk-weighted assets at time t-1 and  $K_{i,t-1}$  is the bank's actual capital level at time t-1. Note that this can also be written as:

$$Z_{i,t} = 100 * \left( \frac{k_{i,t-1}}{k_{i,t}^*} - 1 \right)$$

A negative (positive) value would represent a capital deficit (surplus) relative to the desired, long-run level and banks may react in a couple of different ways. To move towards their internal target risk-weighted capital ratio at time t, given their capital and asset portfolio at time t-1, banks may change the numerator of the capital ratio, by raising or lowering capital levels, or they may change the denominator, by contracting or expanding lending, selling or investing in other assets, and/or by shifting among risk-weighted asset classes. The approach of using lagged risk-weighted assets and capital in the calculation of  $Z_{i,t}$  allows us to avoid potential endogeneity between contemporaneous levels and measures of balance sheet growth.

Hence, the fact that regulatory capital requirements are one of the main determinants of banks' internal capital targets means that this model can be used to make inferences about the bank's response to changes in regulatory capital requirements, which would cause a surplus or deficit relative to the target capital ratio. One problem with the approach to calculating the target ratio using estimates from equation (3) is that data on capital requirements are only available for the period 1996-2007, a period of relatively benign economic conditions in the UK. This limitation means that our parameter estimates may not adequately reflect how banks' capital management practices may respond to changes in capital requirements during more trying economic conditions. Our target capital ratios and subsequent measure of bank capital ratios may therefore also be affected by the fact that equation (3) is not estimated over a full economic cycle.<sup>26</sup>

### **4.3 Estimating the effects of bank capitalization on balance sheet and lending growth**

To assess the impact of capital requirements on banks' balance sheets and lending, we include the capitalization index,  $Z_{i,t}$  (which is a function of capital requirements), as an explanatory variable in regressions of growth in components of each bank's balance sheet, shown in equation (5) below. Banks may respond to surpluses or deficits of capital by altering lending rates or by buying and selling assets, affecting the denominator of the capital ratio. We model assets in three different ways to capture how the composition of assets may change in response to a change in capital requirements: using total balance sheet assets, risk-weighted assets (RWA), and total loans. Note that under Basel I, RWAs

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<sup>26</sup> As a robustness check, we also calculated target ratios for each bank as the mean risk-weighted capital ratio over the entire period the bank is in the sample, as in Hancock et al. (1995) and Gambacorta and Mistrulli (2004). The results in terms of the Z variable were not substantially different from those based on the target ratio equation.

include a measure of exposure to off-balance-sheet assets, so that using the growth in RWAs on the left hand side of (5) captures changes to the overall credit risk and size of the bank's on- and off-balance sheet positions.

Similarly, banks have a number of options for altering their capital levels ( $C_{i,t}$ ). They can raise new capital or retain earnings as a way to manage their capital ratios and overall capitalization in response to prudential regulation, which would result in changes in either total capital or higher quality capital which is a subset of that. These have implications for banks' ability to sustain unexpected losses and probability of failure. Consequently, we estimate two separate models of the growth rates in capital which examine total regulatory capital and comparatively high quality tier 1 capital.

In each of these equations, we include controls for macroeconomic conditions and central bank policy actions, both of which have been shown in previous research to affect bank behaviour. In particular, to measure general macroeconomic conditions and demand for credit, we include real quarterly GDP growth (GDP) and the inflation rate (INF; using the UK Consumer Price Index).<sup>27</sup> As a measure of the tightness of monetary policy, we include changes in the official bank rate set by monetary authorities (BANKR). As a measure of the stage of the credit cycle (which may be distinct from the economic cycle), we follow Berrospide and Edge (2008) in including lagged total charge-offs by banks, as a proportion of bank assets (CHARGE), in each quarter. We also include quarterly dummies to capture seasonal influences. We were not able to control for the extent of non-bank financial intermediation over this period, nor for the development and rapid growth in securitisation during this period, which may mean that our controls do not capture these aspects of financial cycles.

Hence, our specifications for the asset and capital regressions are as follows:

$$\begin{aligned} \begin{Bmatrix} \Delta A_{i,t} \\ \Delta C_{i,t} \end{Bmatrix} &= \sum_{j=1}^2 \lambda_j \cdot \Delta A_{i,t-j} + \beta \cdot Z_{i,t} + \sum_{j=1}^2 \delta_{1,j} \cdot \Delta GDP_{t-j} + \sum_{j=1}^2 \delta_{2,j} \cdot \Delta BANKR_{t-j} + \sum_{j=1}^2 \delta_{3,j} \cdot INF_{t-j} \\ &+ \delta_4 \cdot CHARGE_{t-1} + \sum_{s=1}^4 \rho_s \cdot Q_s + \varepsilon_{i,t} \end{aligned} \tag{5}$$

#### 4.4 Methodology

The capital target model in equation (3) suggests that we employ dynamic panel data techniques that account for the bank-specific component of the error term. Estimating equation (3) using a fixed effects methodology, however, can cause the estimates of the coefficients to be biased, because the lagged dependent variable can be correlated with the disturbance term (see Nickell (1981) for further detail). Simulation results have shown that the bias can be significant even with as many as 30 time periods (see Judson and Owen (1999)). We address this problem using General Method of Moments (GMM) procedures (as

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<sup>27</sup> Data on GDP and monetary policy is provided by Thomson Datastream.

initially discussed in Arellano and Bond (1991) and extended in Blundell and Bond (1998)), which introduce instruments in levels and first differences for the lagged dependent variable, in order to derive unbiased estimates.<sup>28</sup> In order to avoid proliferation of the instruments, which can cause problems with the diagnostic statistics and with the process of weighting the moments, we collapse the instrument matrix as suggested in Roodman (2007), so that there are no longer unique instruments for each time period, and we also restrict the number of lags of the dependent variable in the instrument set (see footnote to Table 2). We use the two-step estimator, adjusting the standard errors by the Windmeijer (2005) correction to counteract bias in the estimates. Long-run coefficients were calculated using the coefficient on the lagged dependent variable,<sup>29</sup> and standard errors are estimated by the delta method.<sup>30</sup>

We estimated equation (5) using a fixed effects estimator. While previous studies have used a partial adjustment method and hence have had to use methods to deal with the bias in the coefficient on the dependent variable (such as system GMM), we found that growth in our balance sheet components was, in most cases, not significantly correlated with its own lags and even where the relationship was statistically significant, it was not sufficiently large to yield an interesting difference between long- and short-run coefficients. Hence, we omitted the lags of the dependent variable from our final model, which also simplifies the estimation since estimation does not require a set of instruments. We chose fixed effects estimation after conducting Hausman and Breusch-Pagan tests to confirm preference for this method over random effects estimation. The total effect of each explanatory variable is calculated by summing over lags of that variable, and once again we use the Delta method to calculate standard errors.

#### **4.5 Description of data and variables**

Because our results have implications for lending activity and economic growth, we focus on evaluating the behaviour of UK commercial banks, which have typically played a large role in supplying credit to large corporations and to small- and medium-sized businesses. Also, commercial banks have traditionally supplied a large share of the consumer lending in the UK.

The data on individual banks' balance sheets comes from the regulatory returns submitted to the FSA (and to the Bank of England as legacy supervisor) and stored in the Banking Supervision Database. The only exception is the return on equity data which comes from the Bankscope database. We restrict our sample to solo and unconsolidated reports due to the UK practice of setting individual capital requirements at the level of the solo entity as well as at the group (consolidated) level. This practice differs from that followed by many other banking regulators that set capital requirements for the consolidated banking group only (for further details, see Francis and Osborne (2009)). Since we are interested in isolating the behaviour of individual banks in response to capital regulation, we believe that evaluating solo-level banking data is important to this analysis. Data on macroeconomic control variables is taken from Thompson Datastream and Bank of England sources.

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<sup>28</sup> We use the implementation of this estimator in Stata by Roodman (2006).

<sup>29</sup> See Gambacorta and Mistrulli (2004) for a description of how this is done.

<sup>30</sup> See Greene (2003), p. 70.

We adjust the data for mergers and acquisitions by creating a new bank after such event, which were identified using Dealogic data on M&A activity by UK banks. Since many structural changes in banks will not feature in this data (e.g. purchase or divestiture of a business line) we further adjust for these events, by creating a new bank whenever both total assets and capital fall or rise by more than 30%. We make further adjustments to the sample to account for extreme and missing values (which can cause large variations in estimated parameters). In particular, to reduce the influence of missing or outlier values, we first drop observations with zeros or missing values for total or risk-weighted assets, the capital ratio, or return on equity,<sup>31</sup> and we also drop banks with loan growth, capital growth or asset growth greater than 50% or less than -50%. We also drop banks with fewer than 10 observations, and, in addition, since we are interested primarily in the impact of capital requirements on banks' balance sheets, we drop banks which have a capital ratio more than 30 percentage points above the required ratio. Although this results in a substantial drop in our sample size (from 8653 to 3851), the sample still contains the largest banks and therefore those banks which are of most interest to a regulator concerned with financial stability. On average over the sample period our sample contains 75% of the assets in the whole dataset.

Table 1 below provides descriptive statistics on the variables used in our estimated equations. Panel A reports information on the data used to estimate equation (3), our capital ratio model. It shows that the average actual capital ratio for the entire sample of roughly 18.3 percent is significantly above the average capital requirement of 11.8 percent. This notable gap is consistent with the notion that banks generally hold sizeable buffers to mitigate regulatory intervention. Capital requirements show considerably less variation within banks than actual capital ratios, which indicates that uncertainty in the actual capital ratio may be one factor motivating banks to hold higher capital ratios than they are required to hold. Both actual and required capital ratios, and indeed most of the variables intended to capture banks' exposure to risk and funding structure, show much more variation between than within banks, suggesting that we might expect differences in capital ratios to reflect diversity in business models specific to banks rather than changes in particular banks' circumstances over time.

The table also shows descriptive statistics for the growth variables used in equation (5) in Panel B. Quarter-on-quarter growth in each of these variables is around 1.5-2.5%. Variation in each of these series is much greater within banks than between banks, reflecting that since these are first differenced variables, differences between banks do not persist over time.

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<sup>31</sup> Dropping those with missing values for return on equity proved to be the most costly step in terms of sample size, since in many cases it proved impossible to match Bankscope records with regulatory returns.

**Table 1: Description of variables used in empirical investigation**

Variable	Mean	Standard deviation		
		overall	between	within
Panel A: Bank variables				
CAPRATIO	18.3	8.2	8.0	3.7
ROE	10.4	16.1	16.9	10.8
CR	11.8	3.1	3.1	1.0
RISK	48.4	20.2	20.9	6.6
PROVISIONS	0.8	2.5	1.7	1.6
TB	8.2	21.6	24.8	5.1
TIER 1	77.2	16.5	15.5	7.1
SIZE	1.0	2.2	2.3	0.2
SUBDEBT	13.0	12.5	11.4	5.6
Panel B: Balance sheet growth variables				
Growth in (percentage):				
Assets	2.3	8.6	2.6	8.3
Risk-weighted assets	2.6	8.5	2.8	8.2
Loans	1.7	14.8	3.4	14.5
Regulatory capital	2.1	7.8	2.1	7.6
Tier 1 capital	2.0	8.4	2.0	8.2

## 5 Empirical results

### 5.1 Target ratio

In Table 2 below we present the long-run coefficients for equation (1) as calculated from the parameters estimated in equation (3), which we subsequently use to calculate the target risk-weighted capital ratio. We also show diagnostic tests which confirm the modelling approach.

Among our set of bank-specific explanatory variables, the most important in determining capital ratios over time are the regulatory capital requirement (CR), and the size of the bank (SIZE). One possible explanation of these findings is that banks set their capital ratios according to the required levels set by the FSA plus a buffer, while larger banks are better diversified and so are able to set a smaller buffer over the regulatory minimum. We also find that our measure of the quality of capital (TIER 1) is positively correlated with the capital ratio in the long run; as is the size of a bank's trading book (TB); banks' return on equity (ROE) is negatively correlated with capital ratios which may reflect the impact of a bank's cost of capital and is consistent with prior research in the same period (e.g., Alfon et al. (2004), Lindquist (2004)), although the relationship we estimate is only weakly significant.

We find that the bank's level of portfolio risk, captured by a regulatory measure (RISK) and a measure of the bank's own view (PROVISIONS), are not statistically significantly related to the firm's capital ratio in the long run, though they have the expected direction of coefficients (negative and positive respectively). We also failed to find a statistically significant relationship with our measure of exposure to market discipline (SUBDEBT), although again this has the expected direction (positive). One possible explanation for this is that the risk adjustments in the calculation of the risk-weighted capital ratio adequately capture the level of risk in the bank's portfolio and banks face no further pressure from the market to hold higher capital against risk exposures. Alternatively, a high level of provisioning may mean that a bank takes a conservative view of the quality of its assets, making it less desirable to hold high levels of capital against unexpected losses. A final possibility is that less risky banks are constrained by regulation to hold the same capital ratios as their more risky peers, and since we deleted those banks with extremely high buffers over regulatory capital requirements (see section 6.5), our sample tends to include those banks which are constrained by regulation.

In order to achieve a reasonable parameterisation of our target capital ratio and hence the measure of capital surplus or deficit, we dropped from the target ratio equation those variables which were not significant in the first specification in Table 2 and re-estimated the equation. We retained ROE since this was only just short of the threshold for significance at the 10% level. Column 2 in Table 2 reports the results for this estimation and shows that the coefficients estimated in this second specification are little changed from those in the first specification. We use the parameters from this second model to compute our measures of capitalization (as described in equation (4)).

**Table 2: Long-run determinants of banks' target risk-weighted capital ratios**

	(1)	(2)
Adjustment (1-2)	0.98*** (0.02)	0.97*** (0.02)
TIER 1	0.08** (0.03)	0.08*** (0.03)
TB	0.05** (0.02)	0.06*** (0.02)
ROE	-0.04 (0.03)	-0.04 (0.03)
CR	0.63*** (0.24)	0.65*** (0.25)
SIZE	-1.39*** (0.33)	-1.25*** (0.31)
RISK	-0.03 (0.02)	
PROVISIONS	0.13 (0.12)	
SUBDEBT	0.03 (0.04)	
CONSTANT	6.65 (4.04)	5.41 (3.35)

Observations	3401	3401
Number of banks	148	148
Number of instruments	98	92
Test for AR(2) in first differences	0.31	0.32
Hansen test (p-value)	0.65	0.57

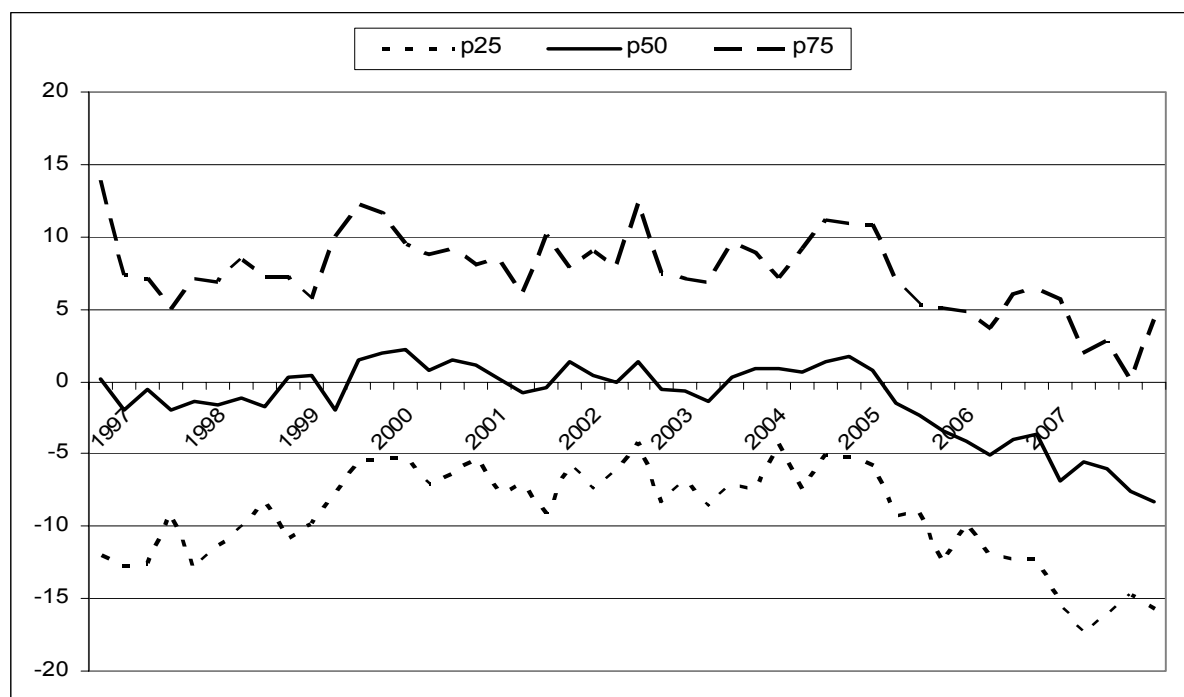
Standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Estimated using system GMM. Instruments are exogenous variables plus dependent variable at lags 2 and deeper.

## 5.2 Bank capitalization

Figure 2 below shows the evolution of bank capitalization,  $Z_{i,t}$ , calculated as in equation (4) to measure a bank's surplus or deficit of capital relative to target capital, over the period of our analysis. We show the 25<sup>th</sup>, 50<sup>th</sup> and 75<sup>th</sup> percentiles in each quarter in order to capture the distribution among banks as well as over time. The figure shows that there is substantial variation across banks, with the gap between 25<sup>th</sup> and 75<sup>th</sup> percentiles being around 15 percentage points for most of the period shown. For much of the period, the series show considerable volatility, although there was a marked decline in capitalization relative to target at all three points in the distribution from 2005 onwards, which may further reflect the relatively higher increase (i.e., relative to capital) in risk weighted assets - and loans in particular - evidenced during this period. The result is consistent with the general downward trend in risk-based capital ratios noted during the last few years of our sample period (see Figure 1).

**Figure 2: Distribution of percentage capital surpluses and deficits ( $Z_{it}$ ) across banks and over time, 1996q2-2007q4**



Source: FSA Banking Supervision Database

### **5.3 Estimation of the determinants of balance sheet growth**

The long-run coefficients from the estimation of equation (5) above are shown in Table 3, separately for models of the growth in the balance sheet measures we model. Deviations from target capital ratio ( $Z_{i,t}$ ) are positively correlated with growth in assets, risk-weighted assets, and loans. Deviations are negatively correlated with growth in regulatory capital and risk-weighted assets. These findings provide support for the idea that banks facing a deficit in their capital level relative to their target capital ratio simultaneously take action to raise regulatory capital levels (e.g., by raising new equity capital or eligible debt or by retaining profits) and to reduce risk-weighted assets (e.g., by raising interest rates on lending, substituting into lower risk-weight categories, or by reducing off balance sheet exposures such as credit commitments).

Furthermore, the results provide support for the notion that these adjustments are largely driven by the need to comply with regulatory requirements in terms of the risk-weighted capital ratio, since adjustment is relatively larger for regulatory capital and risk-weighted assets. The coefficient on risk-weighted assets implies that a 1 percent deficit (surplus) is associated with about a 0.1 percentage point higher (lower) growth in risk-weighted assets. This adjustment compares above that for the loan and asset growth rates, which imply comparable reductions (increases) 0.05 and 0.06 percentage points, respectively. The coefficient on regulatory capital (-0.11) is larger in magnitude than the coefficient on tier 1 capital (-0.08). Since regulatory capital is calculated as the sum of tiers 1, 2 and 3 capital (less deductions which include investments in subsidiaries) the difference in the two coefficients implies that banks tend to favour adjustments to tiers 2 and 3 capital (or to the deductions that they make from total capital) over adjustments to tier 1 capital in this period. This result is perhaps unsurprising given that tier 1 capital is both more costly to raise, and more difficult to alter over time (Berger et al. 1995)). It is consistent with the 'pecking order' hypothesis set out by Myers and Majluf (1984), reflecting the lower costs of adjusting and maintaining lower quality types of capital that make up tiers 2 and 3. These results also suggest that the effectiveness of regulatory interventions intended to raise banks' ability to absorb losses may be somewhat muted unless such capital requirements mandate the type of capital that must be raised.<sup>32</sup>

Amongst the control variables which we included in our estimation, none were consistently statistically significant, which may be due to the fact that the period of our analysis did not include substantial movements in economic conditions or monetary policy. It is possible that banks may have been able to insulate credit supply from the relatively modest fluctuations in macroeconomic variables we observed in this period. GDP was positively correlated with growth in all of the balance sheet measures, which is consistent with the notion that balance sheets appear to grow in size more rapidly during favourable economic conditions. This may be caused by increased demand for loans during favourable conditions. The positive coefficient on capital measures may be due to regulatory requirements which force growth in regulatory capital to keep pace with overall balance sheet growth, or it may reflect the relatively low cost of raising capital during such conditions (e.g. profits are high enough to maintain dividends and retain earnings, and

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<sup>32</sup> The emphasis on the quality of bank capital during the wave of recent recapitalizations across the globe and the international policy agenda focusing on the definition of own funds reflect this issue.

investors are more confident about banks' earnings prospects). The total coefficient on GDP, while positive and consistent with a priori expectations, is not significant for growth in lending, although the magnitude is comparable to the other measures. This may be due to differences between banks in the extent to which customer demand for credit varies over the cycle (e.g., see Huang (2003)).

The base rate set by the Bank of England appears as significant (and positive) in only one specification, the growth in risk-weighted assets. The results, together with the persistently significant coefficient on the capitalization variable, suggest that, at least during the period of our study, the impact of capital requirements played a larger (and potentially more overwhelming) role in effecting credit supply relative to monetary policy actions. Another possible explanation for the positive association, which is contrary to the common understanding that increases in the base rate lead to a contraction in the supply of credit, is that our results may reflect the determination of interest rates: i.e., strong growth in credit supply causes forecasts of future output and inflation to rise, leading the Bank of England to raise interest rates. We note that Berrospide and Edge (2008) in the US, and Gambacorta and Mistrulli (2004) in Italy found negative relationships between lending growth and the interest rate set by those countries' monetary authorities. The difference may be explained by the fact that interest rates in both monetary regimes are set across a range of differing local economies (at state level in the US and at member state level in the Euro area) so the endogeneity of interest rates which we see may be less likely in those countries.

Finally, an additional explanation for the positive relationship between the base rate and asset growth is that while demand for credit in the economy is suppressed by rises in interest rates, it may result in firms becoming more dependent on banks due to the relatively high cost of securing credit from alternative sources during tight monetary conditions. This explanation is cited by one study which looks in detail at the historical relationship between lending and monetary policy stance in the UK (Huang (2003)). This study found that, for the largest firms which account for the majority of borrowing from banks, the relationship is positive when fluctuations in monetary policy are modest, but negative in periods of very tight monetary policy. Since the period of our analysis clearly falls into the former category, it is reassuring to know that our results are consistent with this study.

In contrast, the relationship between growth in measures of regulatory capital and the base rate set by the Bank of England is negative, which may be due to the relative difficulty of raising equity or issuing debt in tight monetary conditions. The same explanation may apply to the negative coefficient between these measures and inflation, since inflation may erode the value of debt and make raising debt capital difficult. Inflation is positively correlated with growth in asset measures, which reflects the fact that these are nominally specified and the nominal stock would tend to rise with inflation.

Finally, the measure of charge-offs is positively correlated with all asset categories, but only statistically significant in explaining growth in risk-weighted assets. This finding may reflect the credit cycle, since there is likely to be a lag between the materialisation of unanticipated losses and those losses being written-off in the bank's accounts. Hence, when banks make write-offs associated with a widespread deterioration in credit conditions,

they may already be raising growth in assets. As might be expected, charge-offs are negatively correlated with tier 1 capital, which reflects the fact that this would be the first buffer against losses.

**Table 3: Regressions of balance sheet components on capital surplus/deficit and macroeconomic control variables**

	Growth in:				
	Loans	Assets	Risk-weighted assets	Regulatory capital	Tier 1 capital
$Z_{it}$	0.05*** (0.02)	0.06*** (0.01)	0.10*** (0.01)	-0.11*** (0.01)	-0.08*** (0.01)
$GDP_{t-1}$	1.27 (1.08)	0.60 (0.60)	0.78 (0.56)	0.48 (0.53)	0.77 (0.59)
$GDP_{t-2}$	0.59 (1.06)	1.06* (0.59)	1.01* (0.55)	0.73 (0.52)	1.03* (0.58)
$GDP_{total}$	1.85 (1.42)	1.66** (0.79)	1.78** (0.74)	1.21* (0.70)	1.80** (0.78)
$Baserate_{t-1}$	1.40* (0.81)	0.50 (0.45)	0.07 (0.42)	-0.31 (0.40)	0.46 (0.44)
$Baserate_{t-2}$	0.31 (0.83)	-0.45 (0.46)	0.05 (0.43)	-0.17 (0.41)	-0.84* (0.45)
$Baserate_{total}$	1.71 (1.27)	0.05 (0.71)	1.78** (0.74)	-0.48 (0.63)	-0.38 (0.69)
$CPI_{t-1}$	1.04 (0.94)	-0.00 (0.52)	0.16 (0.49)	-1.55*** (0.46)	-0.89* (0.51)
$CPI_{t-2}$	-0.34 (0.94)	0.18 (0.52)	-0.11 (0.49)	-0.15 (0.46)	0.68 (0.51)
$CPI_{total}$	0.70 (1.47)	0.18 (0.81)	0.04 (0.76)	-1.71** (0.73)	-0.21 (0.80)
$Charge-off_{t-1}$	16.51 (17.78)	11.83 (9.85)	20.30** (9.25)	0.77 (8.79)	-6.18 (9.70)
<b>Constant</b>	-1.00 (1.98)	1.21 (1.10)	0.25 (1.03)	3.80*** (0.98)	3.35*** (1.08)
<b>Number of observations</b>	3401	3401	3401	3401	3401
<b>Number of banks</b>	148	148	148	148	148
<b>R-squared (overall)</b>	0.01	0.03	0.05	0.06	0.04
<b>R-squared (within)</b>	0.01	0.02	0.04	0.07	0.04
<b>R-squared (between)</b>	0.13	0.26	0.21	0.00	0.00

Standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Estimated using fixed effects panel regression. Quarterly dummies are included but not reported.

## 6 Simulations of changes in regulatory capital requirements

The results described above suggest how banks adjust their capital and assets in response to a change in their capitalization (i.e., surplus or deficit capital relative to target) brought about by a change in capital requirements. By combining the results of the estimation of the target ratio in equations (1) with the results from the asset and capital growth in equation (5), we can simulate the *impact of a change in capital requirements on each of the balance sheet and capital elements considered above*.<sup>33</sup> In this section we show estimates of these impacts, and use these to show the potential effects of a counter-cyclical requirement which raises capital requirements above their usual minimum during a credit boom.

We do this by simulating responses to capital requirements in a model of the UK banking sector. In this analysis, we have assumed that the banking sector as a whole responds to changes in the capital requirements in the same way as we have estimated for individual banks. In order to provide a baseline for our analysis, we calculate the marginal change in the capital surplus/deficit variable ( $Z_{it}$ ) arising from the change in policy, relative to the actual historical path of capital ratios. Then, using the statistically significant parameters shown in Table 3, we translate this into adjustments to the growth rates of each of the 5 balance sheet components. The adjusted growth rates result in an alternative time path for the stock of each of the components, which we can compare to historical values to evaluate the impact of the policy change.

Panel A of Table 4 shows the impact of a single percentage point rise in capital requirements imposed in 2002, in terms of the percentage difference in the stock of balance sheet components from the baseline, without the policy change. The results shown in Table 2 suggest that a 1-point rise in the capital requirement results in a 0.65 point rise in the target ratio, so we use this parameter in the calculation of the  $Z$  variable. Our results show that the adjustment to the new capital requirement is largely completed within four years, with particularly large impacts on risk-weighted assets and regulatory capital, as we would expect from the relatively large magnitudes of the coefficients on  $Z_{it}$  for these variables shown in Table 3. This is consistent with the idea that regulatory regime is an important determinant of banks' capital and asset management. The total effect after 4 years is smaller for assets and loans (-1.41% and -1.16% respectively) than for risk-weighted assets (-2.37%), and the effect of total regulatory capital (2.68%) is greater than that for tier 1 capital alone (1.93%). The relatively small coefficient on tier 1 capital compared to that on total regulatory capital can be interpreted as suggesting that in this period banks tended to alter lower quality capital when responding to surpluses or deficits in capital.

Panel B of Table 4 shows our simulation of the impact of a counter cyclical capital requirement. At the time of writing, the details of how exactly such a counter-cyclical

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<sup>33</sup> The immediate impact of a change in capital requirements on the growth rates of assets and capital can be determined by differentiating equation (5) with respect to capital requirements, using the chain rule to capture the effect of capital requirements on the target capital ratio. However, there may be additional response in later periods to a surplus or deficit of capital relative to target remaining after the initial adjustment, so instead we simulate the impact over an extended time period using dynamic adjustment of the  $Z_{it}$  variable to adjusted risk-weighted assets and capital.

capital requirement might work in practice were still the subject of debate (e.g. see CEBS (2009) and Bank of England (2008)). Here we take a pragmatic approach and assume that the UK authorities had identified an extended credit boom beginning in the late 1990s and ending in 2007, and had implemented three 1-point rises in capital requirements in 1997, 2000 and 2003. These actions imply that at the peak of the boom in 2007, capital requirements would be 3 points above their minimum level, which is consistent with the proposal made in the FSA's Turner Review DP (FSA 2009).

We show the impact of the counter-cyclical capital requirement on the percentage difference between the stock of balance sheet components with and without the new policy in Table 4, and we also chart the stocks themselves, as well as the impact on the capital ratio, in Figure 3. We believe, however, that the assumption of a 65% pass-through may not be justified in this case. While this assumption may adequately capture the average marginal effect of increases in capital requirements, large increases in capital requirements are likely to achieve a pass-through closer to 100%, since otherwise banks would be in danger of breaching their requirement or seriously diminishing their ability to absorb unexpected changes in capital ratio without breaching requirements. Hence, in Table 4 we include the results of the simulation using an assumption of a 100% pass-through, and we also use this assumption to produce the results shown in Figure 3.

The initial analysis in Panel B of Table 4 shows that the counter-cyclical capital requirement achieves its aim (see section 2) of reducing the rapid expansion of credit during this period. The stock of lending falls 3.5% below the baseline by the end of the period, and the impact is larger (-5.18%) when we assume a 100% pass-through, since banks now have to adjust to a higher target capital ratio. However, when considered against the rapid expansion of credit formation during this period, shown in Figure 3, the impact is modest and is far from enough to dampen the upturn of the credit cycle. The impact is comparatively large for risk-weighted assets and capital (10.2% and 12.5% respectively), consistent with a regulatory interpretation of these simulated trends.

The simulations generally show that the policy achieves its other aim of ensuring that at the peak of a boom, banks have target capital ratios which provide a buffer against loan and other losses in the ensuing downturn. The speeds of adjustment implied by the parameters we have estimated mean that by the end of 2007, the banking sector is 3 points above the baseline capital ratio. The timing of the adjustments further implies that the capital ratio is maintained throughout 2000-2007, a period in which historical ratios show a marked decline, as noted in section 2.

**Table 4: Simulated impact of capital requirements on the balance sheet of the UK banking sector**

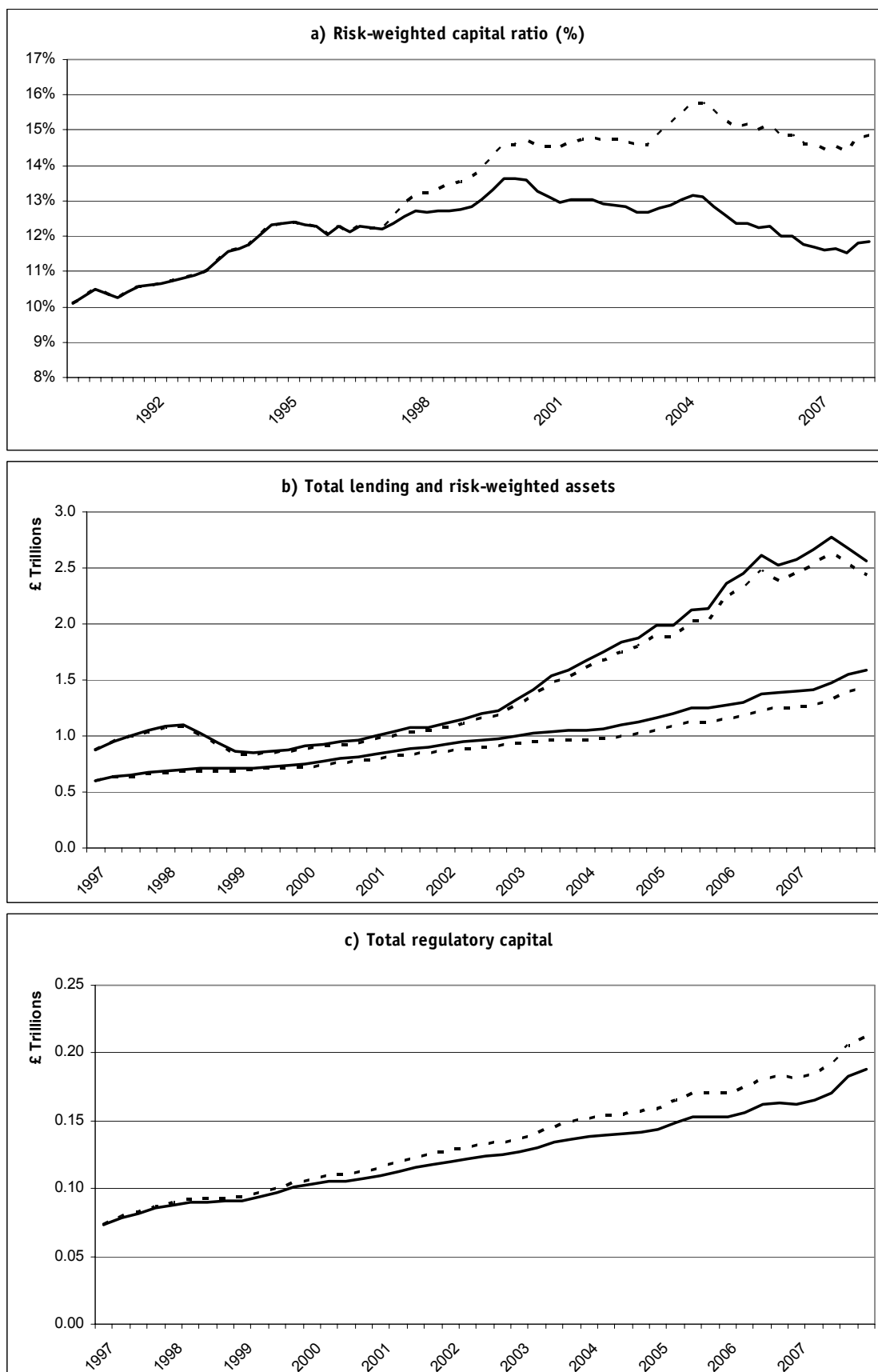
**Panel A: Impact of a 1-point rise in risk-based capital requirement in 2002**

	Difference of stock from baseline after:			
	1 year	2 years	3 years	4 years
<i>Assuming 65% pass-through to target capital ratio</i>				
<b>Growth in:</b>				
<b>Assets</b>	-0.95%	-1.19%	-1.33%	-1.41%
<b>Loans</b>	-0.78%	-0.98%	-1.10%	-1.16%
<b>Risk-weighted assets</b>	-1.59%	-2.01%	-2.24%	-2.37%
<b>Regulatory capital</b>	1.78%	2.25%	2.52%	2.68%
<b>Tier 1 capital</b>	1.28%	1.62%	1.81%	1.93%

**Panel B: Impact of three 1-point rises in capital requirements in 1997, 2000 and 2003**

	Difference of stock from baseline in the last quarter of:			
	2001	2003	2005	2007
<i>Assuming 65% pass-through to target capital ratio</i>				
<b>Growth in:</b>				
<b>Assets</b>	-2.44%	-3.36%	-3.96%	-4.21%
<b>Loans</b>	-2.06%	-2.81%	-3.31%	-3.52%
<b>Risk-weighted assets</b>	-4.06%	-5.60%	-6.59%	-6.99%
<b>Regulatory capital</b>	4.65%	6.51%	7.76%	8.28%
<b>Tier 1 capital</b>	3.34%	4.65%	5.55%	5.92%
<i>Assuming 100% pass-through to target capital ratio</i>				
<b>Growth in:</b>				
<b>Assets</b>	-3.64%	-4.96%	-5.82%	-6.17%
<b>Loans</b>	-3.07%	-4.16%	-4.88%	-5.18%
<b>Risk-weighted assets</b>	-6.04%	-8.23%	-9.62%	-10.19%
<b>Regulatory capital</b>	7.05%	9.84%	11.72%	12.50%
<b>Tier 1 capital</b>	5.05%	6.99%	8.35%	8.89%

**Figure 3: Simulation of a counter-cyclical capital requirement in the UK banking sector, 1989-2007 (dashed lines show simulated series)**



## **7 Conclusions**

This paper has examined the effects of capital requirements on bank capital and lending. Following papers analyzing how balance sheet growth is related to capital adequacy, it explicitly considers the impact these requirements have on banks' desired, long-run capital targets and, in turn, banks' incentives and capacities to lend. Our paper adds to the literature in that it models the impact of the capital requirements set for each bank by the FSA on banks' internal capital targets, and can therefore indicate how banks adjust their lending and other asset components in response to a change in capital requirements set by the regulator.

Our simple theoretical model clarifies the link between capital requirements and lending and shows how, in the presence of capital adjustment costs, the "bank capital channel" implies that higher capital requirements lower a bank's optimal loan growth. That effect, however, depends on the level of excess capitalization, with better capitalized banks (i.e., those with more capital above regulatory thresholds) experiencing less pronounced impacts on their lending. These predictions depend on departures from the Modigliani-Miller propositions and, in particular, increasing marginal costs of capital adjustment.

In our empirical model we find that the bank-specific capital requirements set by the regulator are an important determinant of banks' internal capital targets and that banks' capitalisation relative to an internal target is an important determinant of balance sheet growth, for three different measures of balance sheet size. We find that a 1 percent surplus (deficit) of capital relative to target is associated with higher (lower) growth rates in lending, total on-balance sheet assets, and risk-weighted assets, of 0.05, 0.06 and 0.1 percentage points respectively, whereas it is associated with lower (higher) growth in regulatory capital and tier 1 capital of 0.11 and 0.08 percentage points, respectively. These results suggest that banks adjust assets and capital to move towards their target capital ratio over time. We note that the relatively high magnitude of the coefficients on risk-weighted assets and regulatory capital are consistent with the notion that a regulatory focus on the risk-weighted capital ratio was a significant influence on banks' capital management during this period.

We use these results to simulate the response of banks' balance sheets to changes in capital requirements. More specifically, we examine the response of measures of aggregate industry assets and capital to a 1-point increase in capital requirements in 2002, and find that adjustment is largely completed after four years, at which point the stock of lending is 1.2 percent lower than the baseline and risk-weighted assets are 2.4 percent lower. We also examine how the industry balance sheet adjusts to a counter-cyclical capital requirement such as that outlined in FSA (2009), which has three 1-point rises in capital requirements in 1997, 2000 and 2003. Assuming that the changes in the capital requirement are fully passed through into the target capital ratio, we find that by the end of 2007 lending is 5.2 percent lower than the baseline, and risk-weighted assets are 10.2 percent lower than the baseline. Combined with a significant increase in regulatory capital (12.5 percent), this implies that the UK banking sector would have had a substantial buffer over regulatory minima at the start of the banking crisis in late 2007, and that the counter-cyclical requirement could have had a role in constraining the growth in credit.

## References

- Adrian, T. And Shin, H. S. (2008), "Financial Intermediaries, Financial Stability and Monetary Policy", FRB Kansas City Working Paper prepared for FRB Kansas City Symposium at Jackson Hole.
- Alfon, I., Argimon, I., and Bascunana-Ambros, P. (2004), "What Determines How Much Capital is Held by UK Banks and Building Societies?", Financial Services Authority Occasional Paper no. 22.
- Arellano, M. and Bond, S. (1991), "Some Tests of Specification for Panel Data", *Review of Economic Studies*, 58, 277-297.
- Bank of England (2008), Financial Stability Report, October.
- Bank for International Settlements (2008), 77<sup>th</sup> Annual report.
- Bank for International Settlements (2009), "The Role of Valuation and Leverage in Procyclicality", Committee on the Global Financial System, Report no. 34.
- Barajas, A., Chami, R. and Cosimano, T. (2005), "Did the Basel Accord Cause a Credit Slowdown in Latin America?", IMF Working Paper, no. 38.
- Barrell, R., Davis, E. P., Fic, T., Holland, D., Kirby, S. and Liadze, I. (forthcoming), Capital and Liquidity: How to Calibrate New International Standards, FSA Occasional Paper.
- Berger, A.N., Herring, R.J., and Szego, G.P. (1995), "The Role of Capital in Financial Institutions", *Journal of Banking and Finance*, 19, 393-430.
- Berger, A.N., and Udell, G. (1994), "Did Risk-based Capital Allocate Bank Credit and Cause a "Credit Crunch" in the United States?" *Journal of Money, Credit, and Banking* 26, 585-628.
- Bernanke, Ben S (June 1983) "Non-Monetary Effects of the Financial Crisis in the Propagation of the Great Depression", *The American Economic Review*, The American Economic Association, 73:3 pp. 257-276.
- Bernanke, B. and Blinder, A. (1992), "The Federal Funds Rate and the Channels of Monetary Policy Transmission", *The American Economic Review*, 82:4, pp. 901-921.
- Bernanke, B. and Gertler, M. (1995), "Inside the Black Box: The Credit Channel of Monetary Policy", *The Journal of Economic Perspectives*, 9:4, pp. 27-48.
- Berrospide, J. and Edge, R. (2008), "Linkages between the Financial and Real Sectors: Some Lessons from the Subprime Crisis", Federal Reserve Board Working Paper.
- Bliss, R. and Kaufman, G. (2002), "Explaining Bank Credit Crunches and Procyclicality", Chicago Fed Letter 179, Federal Reserve Bank of Chicago.
- Blum, D. and Nakane, M. (2006), "The Impact of Capital Requirements in Brazilian Banks" Loan Supply", Banco Central de Brazil, Relatório de Economia Bancária e Crédito.
- Blundell, R. and Bond, S. (1998), "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models", *Journal of Econometrics*, 87, 115-143.
- Chiuri, M.C., Ferri, G. and Majnoni, G. (2002), "The Macroeconomic impact of Bank Capital Requirements in Emerging Economies: Past Evidence to Assess the Future", *Journal of Banking and Finance*, 26, 881-904.
- Committee on European Banking Supervision (2009), Position Paper on a Countercyclical Capital Buffer, July.
- Cornett, M. M. And Tehranian, H. (1994), "An Examination of Voluntary Versus Involuntary Security Issuances by Commercial Banks: The Impact of Capital Regulation on Common Stock Returns," *Journal of Financial Economics*, 35, pp. 99-122.

- Covitz, D., Hancock, D. and Kwast, M. (2004), "A Reconsideration of the Risk Sensitivity of US Banking Organization Subordinated Debt Spreads: A Sample Selection Approach", *Federal Reserve Bank of New York Economic Policy Review*, 73-92.
- Diamond, D. and Dybvig, P. (1983), "Bank runs, deposit insurance, and liquidity", *Journal of Political Economy*, 91, pp. 401-419.
- Ediz, T., Michael, I., and Perraudin, W. (1998), "The Impact of Capital Requirements on UK Bank Behaviour", *Federal Reserve Bank of New York Economic Policy Review*, 15-22.
- Ehrmann, M., Gambacorta, L., Matinez-Pagéz, J., Sevestre, P. and Worms, A. (2001) in I. Angeloni, A. Kashyap and B. Mojon (eds.), *Monetary Policy Transmission in the Euro Area*, Cambridge, Cambridge University Press.
- Financial Services Authority (2009), "A Regulatory Response to the Global Banking Crisis", Discussion Paper no. 09/02.
- Francis, W. and Osborne, M., (2009), "On the Behaviour and Determinants of Risk-Based Capital Requirements: Revisiting the Evidence from UK Banking Institutions", *FSA Occasional Paper* 31.
- Friedman, F. and Schwartz, A., (1963), *A Monetary History of the United States, 1867-1960*. Princeton: Princeton University Press (for the National Bureau of Economic Research).
- Furfine, C. (2001), "Bank Portfolio Allocation: The Impact of Capital Requirements, Regulatory Monitoring, and Economic Conditions", *Journal of Financial Services Research* 20, 33-56.
- Gambacorta, L. and Mistrulli, P. E. (2004), "Does Bank Capital Affect Lending Behaviour", *Journal of Financial Intermediation*, vol. 13, No. 4, pp. 436-457.
- Gordy, M. and Howells, B. (2004), Procyclicality in Basel II: can we treat the disease without killing the patient?, Paper presented at the Workshop "Accounting, transparency and bank stability", Basel, 17-18 May 2004.
- Greene, W. (2003), *Econometric Analysis*, Fifth Edition, Pearson Education International.
- Hancock, D., and J. Wilcox, (1994), "Bank Capital and Credit Crunch: The Roles of Risk-Weighted and Unweighted Capital Regulations", *Journal of the American Real Estate and Urban Economics Association* 22, 59-91.
- Hancock, D., Laing, A., Wilcox, J., (1995), "Bank Capital Shocks: Dynamic Effects on Securities, Loans and Capital", *Journal of Banking and Finance* 19, 661-677.
- Hussain, E. and Hassan, K. (2006), "Basel Capital Requirements and Bank Credit Risk Taking in Developing Countries", University of New Orleans.
- Huang, Z. (2003), "Evidence of a bank lending channel in the UK", *Journal of Banking and Finance*, 27, pp. 491-510.
- Jackson, P., Furfine, C., Groeneveld, H., Hancock, D., Jones, D., Perraudin, W., Radecki, L. and Yoneyama, M. (1999), "Capital Requirements and Bank Behaviour: The Impact of the Basel Accord", *Basel Committee on Banking Supervision, working papers* no. 1.
- Judson, R. and Owen, A. (1999), "Estimating Dynamic Panel Data Models: A Guide for Macroeconomists", *Economics Letters*, 65:1, pp. 9-15.
- Kashyap, A., Stein, J.  
(1995), "The Impact of Monetary Policy on Bank Balance Sheets", *FRB Chicago Economic Note*.  
(2000), "What Do a Million Observations on Banks Say About the Transmission of Monetary Policy", *The American Economic Review* 90, 407-28.
- Lindquist, K. (2004), "Banks" Buffer Capital: How Important is Risk", *Journal of International Money and Finance*, 23, 493-513.

*Bank regulation, capital and credit supply:  
Measuring the impact of prudential standards*

- Lown, C., Morgan, D., (2006), "The Credit Cycle and the Business Cycle: New Findings Using the Loan Officer Opinion Survey", *Journal of Money, Credit and Banking* 38, 1575-97.
- Memmel, C. and Raupach, P. (2007), "How Do Banks Adjust Their Capital Ratios? Evidence from Germany", Discussion Paper Series 2: Banking and Financial Studies 2007:06, Deutsche Bundesbank, Research Centre.
- Modigliani, F. and Miller, M. (1958), "The Cost of Capital, Corporation Finance, and the Theory of Investment", *The American Economic Review*, 48:3, pp. 261-297.
- Myers, S. and Majluf, N. (1984), "Corporate Financing and Investment Decisions When Firms Have Information That Investors Do Not Have", *Journal of Financial Economics*, 13, 187– 221.
- Nickell, S. (1981), "Biases in dynamic models with fixed effects", *Econometrica*, 49, pp. 1417-1426.
- Nier, E. and Zicchino, L. (2005), "Bank Weakness and Loan Supply", *Bank of England Financial Stability Review*, December 2005, pp. 85-93.
- Peek, J. and Rosengren, E. (1995), "The Capital Crunch: Neither a Borrower or a Lender Be", *Journal of Money, Credit and Banking*, 27:3, pp. 625-638.
- Repullo, R. and Suarez, J. (2008): "The procyclical effects of Basel II", CEMFI Working Paper No. 0809.
- Rime, B. (1998), "Capital Requirements and Bank Behaviour: Empirical Evidence for Switzerland", Swiss National Bank Working Paper.
- Roodman, D. (2006), "How to Do Xtabond2: An Introduction to "Difference" and "System" GMM in Stata", Center for Global Development Working Paper 103.
- Roodman, D. (2007), "A Short Note on the Theme of Too Many Instruments", Center for Global Development, Working Paper 125.
- Stein, J. C. (1998), "An Adverse Selection Model of Bank Asset and Liability Management with Implications for the Transmission of Monetary Policy", *RAND Journal of Economics*, 29(3), pp. 466-486.
- Stolz, S. (2007), "Bank Capital and Risk-taking: The Impact of Capital Regulation, Charter Value, and the Business Cycle", *Kiel Studies* no. 337, Kiel Institute for the World Economy.
- Stolz, S. and Wedow, M. (2005) "Banks' Regulatory Capital Buffer and the Business Cycle: Evidence for German Savings and Cooperative Banks", *Deutsche Bundesbank, Discussion Paper Series 2: Banking and Financial Studies* No. 07/2005.
- Taylor, A. and Goodhart, C. (2006), "Procyclicality and Volatility in the Financial System: The Implementation of Basel II and IAS 39" in *Procyclicality of Financial Systems in Asia*, ed. by Stefan Gerlach and Paul Gruenwald (Houndsmill, Basingstoke: Palgrave Macmillan).
- Thakor, A. V. (1996), "Capital Requirements, Monetary Policy, and Aggregate Bank Lending: Theory and Empirical Evidence", *Journal of Finance*, 51, 279-324.
- VanHoose, D. (2008), "Bank Capital Regulation, Economic Stability, and Monetary Policy: What Does the Academic Literature Tell Us?", *Atlantic Economic Journal*, 36, 1-14.
- Van den Heuvel, S. (2004), "The Bank Capital Channel of Monetary Policy", The Wharton School, University of Pennsylvania.
- Wagster, J. (1999), "The Basel Accord of 1988 and the International Credit Crunch of 1989-1992," *Journal of Financial Services Research*, 15, pp. 123-143.
- Windmeijer, F. (2005), "A Finite Sample Correction for the Variance of Linear Efficient Two-step GMM Estimators", *Journal of Econometrics*, 126, 25-51.

The Financial Services Authority

25 The North Colonnade Canary Wharf London E14 5HS

Telephone: +44 (0)20 7066 1000 Fax: +44 (0)20 7066 1099

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